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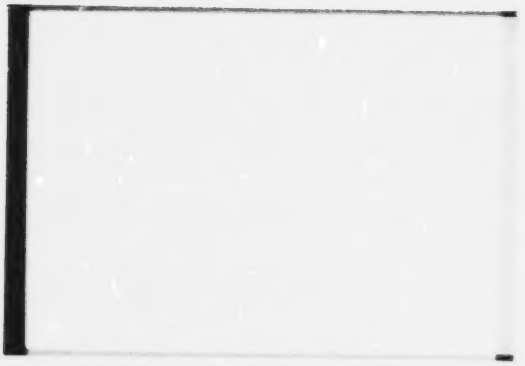

ACCOMPLISHMENTS OF THE

NEW LIQUID FUELS TASK

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ACCOMPLISHMENTS OF THE NEW LIQUID FUELS TASK

Introduction

The New Liquid Fuels Task (NLF) was formed in 1980. Up until then research in this area was modest and done mainly at CANMET, with some work at NRC and TC. Since 1980, the work has been coordinated by a Task Coordinator within the Transportation Energy Division (TED), EMR. TED is responsible for federal policies and programs for alternative transportation fuels, which are the main focus of R&D in the NLF Task. For the purposes of the task, New Liquid Fuels are defined as those fuels equivalent in use to conventional oil-based fuels. This includes liquid fuels, gaseous fuels and electricity.

The general objective of New Liquid Fuels R&D is to provide the technical basis for:

- maintaining oil and energy self-sufficiency in future years by providing practical and economic alternatives to conventional petroleum through the use of coal, bitumen, natural gas, gas liquids and biomass;

- developing the techniques to ensure environmental protection and health and safety during the production and use of new liquid fuels;

- creating opportunities for industrial growth and use of domestic resources as sources of liquid fuels, especially bitumen and natural gas; and

- laying the technical and regulatory foundation for a major transition to alternative fuels in the next century.

The federal role in new liquid fuels R&D recognizes that:

- Canadian reserves of conventional petroleum are being depleted and that the Canadian transportation system relies almost exclusively on this resource;

- alternative sources (e.g. oil sands, natural gas, coal) for transportation fuels will thus be required in Canada;

- alternative fuels "at the pump" (e.g. compressed natural gas, neat alcohols and alcohol/gasoline blends) will become increasingly attractive;

- the federal government traditionally plays the lead role in setting standards, practices and procedures in the fuels and vehicle areas even though much of the legislation is the responsibility of the provinces;

- the federal government has the specific responsibility for some standards, such as used by the military;

- the federal government supports longer-term research, sharing the costs with industry and laying the technical groundwork for market penetration of alternatives fuels; and

- the federal research program provides the technical support for alternative fuel demonstration programs (e.g. for methanol blends) which are funded in whole or in part by the federal government.

The Task strategy is first to identify the most promising alternatives to those fuels produced from conventional crude petroleum. Once identified, the next step is to develop the technology for producing and using such fuels. The final step is to encourage the technology transfer, which includes the establishment of various safety and regulatory standards and practices for the orderly introduction of alternative fuels into the market place.

The research projects are thus governed by the above strategy. Distant alternative fuels, such as hydrogen and electricity, are at a stage of basic research. Nearer term fuels such as methanol are being closely studied for their economics of manufacture and use; also, regulations must be based on the best knowledge and pilot projects must transfer technology to the commercial marketers and users.

It follows that the accomplishments of the New Liquid Fuels Task fall along the whole spectrum, from near fuels to distant fuels. For convenience, these accomplishments are listed according to the eight programs of the New Liquid Fuels Task, which are defined below:

5.1 Direct Liquefaction - production of liquid fuels by the direct liquefaction of coal, biomass or mixtures of coal with bitumen, heavy oils and residues;

5.2 Gasification - production of liquid fuels by the indirect liquefaction of coal or biomass in which gasification is an essential step;

5.3 Biological Processes - production of liquid or gaseous fuels from biomass by biological processes;

5.4 Fuels Processing - production of liquid fuels by the upgrading of synthetic crudes and the conversion of natural gas to liquid fuels;

5.5 Fuel Use - establishing the technical, economic and regulatory basis for the efficient, safe and timely deployment of new liquid fuels, or wider boiling range fuels from conventional or synthetic crudes, for use in transportation;

5.6 Hydrogen and Energy Storage - production, storage, distribution, safety and end-uses of hydrogen and energy storage in general, including storage of electricity for use as a transport fuel;

5.7 Environment - study of the environmental impacts of new liquid fuels and abatement technologies; and

5.8 Coordination - planning and coordination of new liquid fuels research and federal policy development.

A general accomplishment for Canada in the alternative fuels area is reflected in the finding that we now have about 120,000 propane vehicles and about 5,100 CNG vehicles. It is estimated that about 20,000 b/d of oil are replaced by alternative fuels. Ethanol blend and methanol/ethanol blend gasoline is sold at a number of outlets on the prairies for use by unmodified vehicles. Methanol/iso-butyl alcohol/gasoline blends are also sold under the name "V Plus" in southwest Ontario. The 10% ethanol/gasoline blend receives a 2.5¢/l. tax concession (this translates into a 25¢/l. tax concession for ethanol).

The first group of accomplishments to be discussed are studies of a general nature in support of policy and strategy development.

Techno-economic Studies to Support R&D Strategy Development

The first study to be mentioned, the Alternative Fuels Production Costs, afforded plant gate production costs (Edmonton location, fourth quarter 1980, 1990, and 1985) for alternative fuels according to some 44 selected processes. This study showed that most alternative liquid fuels are at present more expensive than conventional fuels but certain of them, particularly if untaxed, would cost less at the pump than current gasoline or diesel fuels. Propane extracted from natural gas was shown to be the most cost-effective alternative fuel, followed by compressed or liquified natural gas.

The methodology for calculating alternative fuel production costs was used to develop a computer program, called the Alternative Fuels Economic Model, which is available from the Transportation Energy Division of EMR. The input parameters for the program may be changed by the operator so that calculations can be performed for any location and/or feedstock costs.

A second study, the Alternative Fuel Cost Study, determined the life cycle costs (cost per passenger kilometer for passenger cars or cost per tonne kilometer for freight vehicles) for various types of passenger (Honda CRX, Ford Fairmont Futura, Pontiac Parisienne, International Harvester (school bus), GM "New-Look", Prévost Marathon and Dodge Pick-up, D150 RAM) and freight-carrying vehicles (Ford F150 Pick-up, International Harvester Loadmaster, Ford and Cummings trucks). The fuels examined in the study were: regular leaded gasoline, diesel, CNG, LNG, propane, methanol (neat, in a blend of 4.75% methanol and 4.75% tertiary butyl alcohol in gasoline and as 90% methanol with 10% gasoline), and gasohol (10% ethanol blend in gasoline). A total of 64 different cases were examined. Propane and CNG provided usually the lowest life cycle costs among the fuels investigated. These costs are being verified by fleet operators.

The Economic Analysis Section of TED performs periodic economic assessments of propane and natural gas as transportation fuels. The latest analysis, performed in February 1985 and based on mid-1983 data, calculated the social supply prices (defined as the resource cost or value to the country - excluding transfer payments - of using a particular fuel) for gasoline, propane and natural gas. The social supply price of unleaded gasoline, based on world oil prices adjusted for transportation costs and refinery and distribution margins, is 38¢/l. The social supply price of propane, based on its value in the export market plus incremental transportation cost, the cost of vehicle conversion and fueling facilities at gas stations, is between 28¢/l. (gasoline equivalent) for taxis and 38¢/l. for agricultural trucks. The social supply price of natural gas, based on the Toronto City Gate price, is between 25¢/l. (gasoline equivalent) for taxis and 43¢/l. for agricultural trucks. These calculations include a conversion cost of $1500 for propane and $1800-2500 for natural gas vehicles. For commercial vehicles, both propane and natural gas fuels provide a real savings from 6 to 10¢/l. (gasoline equivalent).

The difference between gasoline-alternative fuel social supply prices represents a net economic benefit for Canada. These equal approximately $140 million (discounted at 7%) for the 47,000 vehicles converted under the Federal Propane Vehicle Program as of November 1984. For all propane vehicles in Canada, the net economic benefits would be about $280 million. If 100,000 vehicles are converted to natural gas between 1985-2000, the net economic benefits to Canada would be about $270 million (discounted at 7%). The financial attractiveness of gaseous fuels depends on the type of vehicle and mileage. In general, natural gas vehicles exhibit a lower payback period than propane in all categories. For example, the payback period without grants for taxis and commercial automobiles is about 0.4 and 1.6 years for natural gas and 2.7 and 2.9 years for propane, respectively.

Hycarb Engineering Ltd. performed an optimized linear program analysis of the effect of oxygenated fuels on Canadian oil refineries. The scenarios investigated included the addition (to a maximum of 11%) of methanol and a co-solvent (ethanol, iso-propyl alcohol, iso-butyl alcohol or tertiary butyl alcohol (TBA)), ethanol, or methyl tertiary butyl ether (MTBE) to unleaded gasoline as an alternative to toluene purchase or investment in octane boosting technologies (e.g. isomerization or reformer units). Given the March 1985 market conditions, only the 5% methanol - 3% ethanol oxygenate appears to be economic (with low cost imports of ethanol from Latin America). By 1990, with proposed tetraethyl lead levels of 0.29 g/l. Pb, coming into effect on January 1, 1987, methanol/TBA, ethanol and MTBE oxygenates (produced indigenously) could be economic.

Program 5.1 - Direct Liquefaction Program: **To develop direct liquefaction technologies using fossil fuels or biomass as feedstocks.**

Co-Processing of Coal and Bitumen - CANMET (51101, 51102)

In Canada, large reserves of coal and bitumen or heavy oil are located in close proximity and offer the unique possibility of co-processing. This concept refers to the hydroprocessing of mixtures of coal and bitumen or heavy oil, where the coal is liquified and the oil upgraded simultaneously. This concept is similar to a direct coal liquefaction process in which the coal-derived recycle oil is replaced with externally supplied bitumen (or other solvent). Alternatively, it can be viewed as an extension of the CANMET hydrocracking process although with much larger coal concentrations (up to 40%) used in the feedstock.

The major accomplishments of the research program to date have been in successfully demonstrating the co-processing concept using continuous-flow bench-scale equipment and showing that it can be developed as a logical extension of the CANMET hydrocracking process now being commercialized by Petro-Canada and Partec Lavalin.

Autoclave and continuous bench-scale experiments (1 kg/h) carried out at CANMET's Synthetic Fuels Research Laboratory in Ottawa have demonstrated the feasibility of co-processing Forestburg subbituminous C coal and Cold Lake vacuum bottoms. Co-processing of these feedstocks was compared with coal liquefaction and hydrocracking under identical operating conditions. Co-processing has been shown to be technically superior to coal liquefaction processes in that total oil yields are more than four times greater with equivalent coal conversions and it has better hydrogen utilization efficiencies. More importantly, in comparison with bitumen or heavy oil hydrocracking, co-processing has been shown to produce almost equivalent oil yields with up to 40% moisture ash free (maf) subbituminous coal in the slurry feed. With a cost ratio of whole bitumen to maf subbituminous coal of more than 3 to 1 on an equivalent weight basis, the economic potential of co-processing cannot be ignored. Techno-economic studies have been started (by Partec Lavalin Inc., under contract) to better quantify the relative economics between co-processing and hydrocracking based on experimental results and data generated to date.

The demonstrated viability of the technology has led to the construction of a 0.5 t/d pilot plant at CANMET to investigate longer term process operability. Construction of a 10 t/d process development unit in conjunction with a process developer is also being considered. The unit would be flexible enough to run in either the hydrocracking or co-processing modes. Currently, CANMET is negotiating an extension of the hydrocracking licensing agreement with Petro-Canada to include co-processing as a first step in the eventual commercialization of the technology.

Coal liquefaction Program - CANMET (51204)

The in-house coal liquefaction program includes the construction and commissioning of two 1 kg/h bench-scale coal liquefaction units, the investigation of coal liquefaction at low temperatures and pressures using bitumen solvents (two-stage coal liquefaction), organometallic compounds as liquefaction promoters, and participation in the National Coal Conversion

Coordinating Committee. This committee provides technical advice to the Interprovincial Advisory Committee on Energy (IPACE) and is presently involved in the preparation of a position paper on coal conversion in Canada, to be completed in 1985.

The contracting out program is sponsoring coal liquefaction studies using liquid clathrates at the University of Victoria, coal petrography studies at the University of Regina, two-stage coal liquefaction studies at the Nova Scotia Research Foundation Corporation, the evaluation of foreign coal liquefaction pilot projects with a view to eventual Canadian participation (by the Sandwell Beak Research Group, the developer of a unique solids separation process for coal liquefaction, and others), evaluation of spherical agglomeration by SNC Inc. of Montreal, and continuous liquefaction studies - determination of product yield and quality of Hat Creek coal - at the B.C. Research Council. This contracting out program, which was started in 1976, has established centres of expertise in B.C., Ontario and Nova Scotia. The program complements activities by the Alberta/Canada Energy Resources Research Fund which supports a major coal liquefaction R&D program of the Alberta Research Council. The program also complements those activities related to coal liquefaction being considered under the Canada/Saskatchewan Agreement on Heavy Oil and Fossil Fuels R&D. Annex B contains a list of contracts awarded by CANMET.

Canada is cooperating under the Canada-Japan and Canada-West Germany S&T consultations with these countries in the area of coal liquefaction.

International Energy Agency Agreements: Biomass Liquefaction Test Facility - NRC (51201)

Sweden is the project manager of a four nation (USA, Canada, Finland) techno-economic assessment of the direct liquefaction of forest biomass under an IEA agreement. The Canadian participation, federally funded and coordinated by the Bio-Energy Program of NRC, involves several universities (Waterloo, Sherbrooke, Toronto, and Saskatchewan). The study converged on two processes, a low-cost rapid pyrolysis process followed by upgrading of the oil product, and a solvolysis and separation route, which is a more complex process, requiring a longer residence time, but can produce benzene, toluene and xylene (BTX), phenol and other chemicals.

During the first stage, several process concepts for biomass liquefaction were examined. The oils produced in such processes are similar in consistency to #4-#6 fuel grades. The final report for this stage was released in 1983, and recommended further work on processes and upgrading prior to investing in a large scale pilot plant.

Demonstration of Liquid Fuel Production from Sewage Sludge - EC (51201)

This is a project under investigation by the Environmental Protection Service, Wastewater Technology Centre (WTC), Burlington, Ontario.

Sewage treatment plants generate 1 tonne of sewage sludge for every million gallons of sewage. Presently, the disposal of sewage sludge costs from 126 dollars/tonne for agricultural utilization to over 300 dollars/tonne for incineration, for a total cost of 104 million dollars per year in Canada. An

alternative disposal procedure, in keeping with the co-product credit theory for biomass (see Program 5.3), is to pyrolyze the sludge at 350-450°C and atmospheric pressure, in the presence of Al silicate/Ni/Cu catalysts. The end products are a non-condensable gas, a char and an oil. The non-condensable gas contains methane, ethane, hydrogen, carbon monoxide and carbon dioxide. The char, having the appearance of a finely divided coal, has the heating value of a poor quality lignite (10 MJ/kg) and an ash content of 50-60%. The oil contains a mixture of C_9-C_{20} alkanes and alkenes and carboxylic acids. Aromatic hydrocarbons were present only in traces. The elemental composition of the oil shows high oxygen (8-12%), and nitrogen (3-4%) levels although the sulphur and heavy metals levels are lower (less than 0.5% and 5 ppm, respectively). This oil competes against the #6 heating fuels. Further upgrading will be necessary for other uses. CANMET estimated the cetane number of the oil to be 54; NRC is now in the process of determining experimentally this cetane number. For every tonne of sludge, this process produces about 500 kg. of char and 2 bbl. of oil.

The experiments are carried out at WTC (by Dearborn Environmental Consultants) on a continuous installation having a capacity of 1 kg/h of sludge. Preliminary calculations on this process showed favourable economics for sewage treatment plants serving a population of at least 100,000. The cost of such a pyrolysis plant would be the same as or lower than the cost of a sludge incineration disposal plant. Communities of this size produce about 25 tonnes of sludge per day. The total sludge generated in all such communities in Canada would be about 350,000 tonnes/year, which translates into 700,000 bbl/year of oil.

A contract awarded to Zenon/Xytel Consultants in June 1984 deals with the process design and capital costing of a 25 tonne/day demonstration facility, site selection, product characterization and a market survey. Two municipalities are interested in this process of sludge disposal and are prepared to contribute towards this demonstration facility.

Professor E. Bayer of Tubingen University, West Germany, the inventor of this process, has been granted patent protection in Canada (Canadian patent 1,182,062). WTC has produced some improvements to this process and has filed a patent application in Canada, U.S., Japan, U.K., France, Germany, Austria, and the Netherlands. The WTC application refers to the apparatus for and control of this process. EC has also signed an agreement with Professor Bayer, which gives EC exclusive rights for his process in North America. EC is now soliciting interest from Canadian corporations to be licensees of this technology (Globe and Mail, April 20, 1985).

Program 5.2 - Gasification Program: **To develop gasification technologies for the indirect route to producing liquid fuels.**

Coal Gasification - CANMET (52101)

Coal gasification is part of an indirect route to producing liquid fuels. Federal activity is located at CANMET's Hydrocarbon Processing Research Laboratory. The program is four years old.

A study, funded 50-50 with the Ontario Energy Corporation, has estimated the costs of methanol produced by the indirect route from the large Onakawana lignite deposits of Ontario to be 20 cents per litre (assuming a 9.5% rate of return). The steps are coal to syngas to methanol, the latter by the I.C.I. process. The Onakawana Corporation is using this study in its decision to proceed with or to defer production.

CANMET (50%) has joined with Westar Engineering Company (25%) and Esso Resources Canada (25%) in a feasibility study to convert coal rejects to transportation fuels by the indirect method. The study is not yet complete, but the participation with industry holds promise for application. Furthermore, the study's results could be applied to oil sands coke or to the Onakawana lignites.

The first part of a project on the selection of gasification processes for the very large stockpiles of coke from oil sand projects has been completed. CANMET in-house studies of Syncrude and Suncor cokes have eliminated fixed bed and fluidized bed gasification technologies for gasification. The entrained bed gasification technology appears appropriate, followed by Fischer Tropsch synthesis. This is currently used by Texaco in the U.S. to gasify solid feedstock in the form of water slurry. CANMET has determined that the end product of this indirect route will be paraffin-rich and could then be mixed with the current synthetic crude to offset its high aromaticity.

A centre of expertise in spouted and fluidized bed gasification technologies has been created at the University of British Columbia. Bench-scale gasifiers have been built and are used in graduate studies as well as for research. The Department of Chemical Engineering and Coal Research Centre at UBC has, for example, conducted, under contract to CANMET, a comparison of coal gasification in fluidized and spouted beds. The two gasifiers gave remarkably similar results for the coals tested. The caking and non-caking coals (a caking coal becomes sticky when heated through the plastic stage and can cause problems by agglomerating on the grid in a fluidized bed) were readily gasified with an inert bed in either spouting or fluidized bed mode, producing a gas with similar heating values, yield and thermal efficiencies. Small advantages appeared to accrue to the fluidized bed for Roselyn coal, and to the spouted bed with Balmer rejects. No differences were found for Sukunka and Forestburg coals. Klimax coal posed problems in both gasification modes, due to an interaction between the coal ash and the inert bed material. New advantages/disadvantages of these two modes of gasification may become obvious on scale up.

Negotiations with China, SNC and UBC may lead to the opportunity for export of the spouted bed gasification technology.

CANMET has constructed, at its Bells Corners facilities, equipment in support of its gasification studies. These included bench-scale versions of a continuous fluidized-bed gasifier, a fixed bed gasifier and a thermal balance reactor. These units are equipped with analytical systems to monitor the composition of gasification products on-line.

A service to industry has been performed by CANMET in the form of published reports (explanation, data, interpretation) on the gasification characteristics of Canadian coals.

The gasification characteristics of Canadian coals are essential information for companies with plans to embark on indirect liquefaction and for governments to understand the feedstocks for liquid fuels. These gasification reactivities were evaluated at the bench scale using a fixed bed and a fluidized bed facility. The latter was recently built and is capable of operation at and above atmospheric pressures. The facility is also equipped with a system enabling hot gas clean up studies (i.e., at the gasification temperature, about 800°C).

Hot Gas Cleanup - CANMET (52103)

CANMET has developed a technique for the cleanup of hot gases. Patents have been applied for. Conventionally, cleanup occurs at low temperature; the hot gas must be cooled for cleanup and then reheated for further processing. The CANMET technology permits cleanup at the gasificaton temperature of about 800°C. The potential application goes beyond coal gasification and could be used in combined cycle power generation. The absorbent for H_2S at high temperatures is the red mud by-product of aluminum production and naturally occurring clay-like materials. CANMET's research suggests that, if the technology were used to extract the H_2S from its hydrocracking process, that only the sulphur would be taken up and the hydrogen could thus be available for upgrading. This is the first year of this promising project.

Pressurized Fluidized Bed Wood Gasification (Biosyn, 52201)

The major portion of gasification funds was directed towards one project, the pressurized fluidized bed gasification of wood. This project is managed by Biosyn, a consortium which includes Nouveler Inc., a subsidiary of Hydro Quebec, S.G.F., Rexfor and Soquem. The federal interest is currently held by Petro-Canada.

The project comprises the design, construction and operation of a pre-commercial oxygen blown fluidized bed gasifier based on the Omnifuel technology. The gasifier will have a capacity of 5 to 10 tonnes of oven dried wood per hour and will operate at pressures of 1.2 - 2.1 MPa. The product will be a medium joule value (MJV) synthesis gas. The location of the pilot plant is St. Juste de Bretenières, Québec.

The project is divided into four phases:

1) A preliminary engineering design and feasibility study to provide preliminary engineering drawings and detailed cost estimates.
2) Detailed engineering design and construction (12 months).
3) Commissioning and debugging of the unit.
4) Long term tests - three months continuous operation.

EMR obtained Treasury Board approval to enter into an Agreement with Biosyn to contribute one-third of the estimated total cost of the project to a maximum of $5.93 million (1982-83$). Biosyn contracted Phase 1 of the project to SNC Inc. of Montreal. Phase 1 is now complete. The most recent (November 1982) estimation for the cost of the project is $21.6 million (1982-83$).

Phase 2 is currently underway. SNC Inc. has been retained as Project Manager. The Project Manager experienced some delays in awarding contracts. Foundation work was started in January 1984 and in October 1984 there were 104 persons working at the site.

Following the success of the Omnifuel/Biosyn gasifier, Biodev International of Montreal, a company having as partners SNC and Nouveler, was awarded a 9M$ contract by Electricité de France to build a wood gasifier in the French Guiana. For this and future projects, Biodev is associated with the French company Alsthom-Atlantique, which produced a diesel engine capable of using as fuel the gas delivered from a wood gasifier. The French Guiana project involves the construction of a 6.7 MWe power plant, which uses 5 tonnes of wood per hour as fuel. This installation will be built at Electricité de France's Degrad des Cannés power plant. It is estimated that Biodev entered an export market with a potential value of 200 M$ over ten years (Le Devoir, October 26, 1984).

Molten Salt Gasification - NRC (52202)

Molten salt gasification, being studied by SNC Inc. of Montreal for NRC, offers an oxygen-free pyrolysis route to synthesis gas. The reactor containing the salt is electrically heated. A total of thirteen experiments were performed on behalf of SNC at the U.S. D.O.E. developed facility in Rockwell. The molten salt gasifier is an alternative to the fluidized bed gasifier.

Program 5.3 - Biological Processes Program: **To develop technologies for the production of liquid or gaseous fuels by various biological processes.**

Biological Production of Fuels - NRC (53101)

For wood feedstocks, anaerobic microorganisms such as Acetivibrio cellulolyticus and Bachteroides cellulosolvents were found to produce cellulases (that is to break down cellulose to individual sugars). New microorganisms, such as Pachysolen tannophilus, were isolated, and improved to convert five-carbon sugars to alcohol and wood hydrolysate streams. Studies of the enzymatic hydrolysis of wood using Trichoderma Reesei have shown that further process optimization in enzyme production and cellulose hydrolysis is possible.

Biomass Conversion to Liquid Fuels - Agriculture Canada (53201)

Agriculture Canada's major initiative (under the ERDAF Program) is the development of a flexible farm scale fuel alcohol (ethanol) production system by fermentation. This project is located in southern Ontario. The contractor is 474706 Ontario Ltd. which holds the option to purchase the facility. The company has constructed and debugged the facility and is now demonstrating its year-round capability since as of the summer of 1984, it had not yet had a winter's trial of the outdoor, insulated distillation equipment. One of the promising settings for such a plant are in southwest Ontario, where there is cheap gas for process heat below site. Another promising location is the Bruce Peninsula where the Resolute Development company is considering using the cheap steam from Ontario Hydro's facilities. Agriculture Canada will produce handbooks of this technology.

Another ERDAF project is the development of systems (small on-farm or larger farm cooperative/industrial scale) for denaturing fuel ethanol (i.e., making the alcohol unfit for human consumption) as it comes from the distillation column. This would make the fuel exempt from excise duty and eliminate the requirement of alcohol collection in a "locked" receiver. This in turn means minimum supervision by Revenue Canada. Components of the denaturing system developed by Canadian Food Products Development Centre and Wardrop & Assoc. Ltd. are presently undergoing preliminary testing at Mohawk Oil's fuel ethanol distillery in Minnedosa, Manitoba, where 8 million litres of ethanol are produced each year. Wellington Engineering has designed an alcohol denaturing system that can be applied to smaller scale plants such as the AC Watford facility.

The University of Western Ontario evaluated the potential of producing ethanol from Jerusalem artichokes and Fodder beets. The evaluation resulted in the development of novel free and immobilized cell fermentation processes. The experimental data was incorporated in a preliminary process design for a community scale plant (1×10^6 l./yr) to convert energy crops to ethanol.

St. Lawrence Reactors Ltd. conducted a study at the pilot level on Jerusalem artichoke hydrolysis for ethanol production using the SLR plug flow acid

catalyzed reactor. The pilot study resulted in the development of a process incorporating the SLR reactor. SLR is in the business of reactor design and marketing and therefore, in a good position for technology transfer.

Iotech Corp. evaluated the production of cellulase enzymes using agricultural lignocellulosics as substrates. This work is complementary to previous studies conducted with wood substrates and provides information that is useful for the process development of ethanol from agricultural residues at the Iotech/Monenco pilot plant.

Forintek Canada (Eastern Laboratories) conducted fundamental studies on the enzymatic hydrolysis and fermentation of agricultural residues to ethanol and other potential co-solvents. This work is complementary to other Forintek studies on wood and provides much useful data for further process development and scale-up.

The Ontario Research Foundation has undertaken, in collaboration with Perkins Engines, a major engine manufacturer, the design and development of a microprocessor controlled fuel delivery system for the use of ethanol in diesel tractors. The technology is now at the field testing stage. The system can achieve up to 30% substitution with ethanol.

Ethanol from Cellulosics - EMR (55302)

The program began in October 1981, with the designation of Canertech Inc. as the lead agency in the development of a wood to ethanol pilot plant and related R&D activities. The feedstock chosen was hardwood poplar, Populus tremuloides, found throughout Canada. This species grows well on marginal land, has a history of being under-utilized, and has lent itself very well to hybrid development.

Poplar hardwood (dry basis) contains 20-21% lignin, 50-52% cellulose and 22-24% hemicellulose. These constitutents are polymers formed from glucose (cellulose), certain pentoses and hexoses (hemicellulose) and phenylpropane units (lignin). Only the cellulose and hemicellulose can be converted to a theoretical maximum of 450 litres of ethanol from 1 tonne of dry wood. Lignin is a byproduct, which can be burned, or upgraded to higher value products such as glues, phenols or other chemicals.

Schematically, the technology to produce ethanol from lignocellulosics consists of the following processes:

a) Separation of the cellulose and hemicellulose from lignin;
b) Conversion of both the cellulose and hemicellulose to monomeric sugars; and
c) Fermentation of monomeric sugars to ethanol.

In the process chosen by Canertech, the poplar is first dried to about 10% moisture (it was found that natural wood drying can be carried out at 50% humidity to obtain this moisture level). Treatment with anhydrous hydrofluoric acid breaks down the polymers to about 6-16 sugar units

(oligosaccharides). The hydrofluoric acid is then desorbed at better than 99% recovery. The oligosaccharides are then further broken down to individual sugars with dilute acid, and the lignin is removed by filtration. Conversion of the wood to sugars has given yields of hexose sugars in excess of 90% of the theoretical and 75% of the theoretical pentose sugars.

Fermentation studies are conducted by a contractor in cooperation with the National Research Council in Ottawa and deal with pentose and hexose sugars fermentation. About 500 strains have been evaluated for pentose fermentation, of which seven have been selected for intensive studies. For hexose fermentation, a mutant of Clostridium saccharolyticum has shown good conversion efficiencies for both glucose and xylose and increased tolerance to ethanol. Preliminary studies have indicated yields of 300-400 litres of ethanol per tonne of dry wood.

Until June 30, 1984, these investigations were conducted by Canertech Inc. in a test unit at the University of Manitoba. As of July 1, 1984, this work is being carried out by Allose Manitoba Ltd. under contract from the Renewable Energy Division of EMR.

The overall objective of the program over the next two to three years is to reach a stage in development where a pilot plant is designed in detail (but not built), and a complete conceptual process design for a commercial size plant is completed along with an evaluation of the technical and economic feasibility of the technology.

This objective will be reached in two phases. Phase 1 includes largely research and development activities as described above. Phase 2 will include the detailed engineering design of a pilot plant and a techno-economic feasibility study.

A Phase 3, involving the procurement, construction and operation of a pilot plant might occur based on the positive results of Phases 1 and 2.

Bioenergy Development Program - EMR (53401)

Under the Bioenergy Development Program (BDP) support is given for the R&D of new technologies and methods that would further advance the use of bioenergy in Canada's energy supply. Some developments nearing commercialization which have arisen from R&D to date are described below.

Research and development on the production of liquid fuels and chemicals from vacuum pyrolysis has yielded positive results, and enabled the University of Sherbrooke to approach various industry groups interested in the commercial applications of this type of technology. This had led to an agreement between Petro Sun International of Montreal and the University of Sherbrooke for the establishment of a vacuum pyrolysis pilot plant.

Prince Albert Pulp company is evaluating the potential of tall oil, produced from soap skimmings recovered from the black liquor of kraft plants, as a fuel

in mobile equipment for woodland operations. The company has made substantial progress towards the implementation of tall oil as a diesel fuel substitute and, in Phase 2 of the project, intends to perform field trials on the most promising fuel blends. Prince Albert estimates that one-quarter to one-half of the diesel fuel used to provide wood to a kraft softwood pulp mill could be replaced by tall oil. The company is now applying to patent a process for the separation of lignin from tall oil.

Iotech Corporation has successfully completed some enzyme production scale up tests using commercially practical operating conditions provided by the Corning facility in the United States. These tests have indicated a large productivity improvement for the enzymes and have reduced currently projected capital cost estimates for ethanol production by 25%. The scale up tests will identify problems which could occur at a larger commercial scale in order to help focus pilot plant design optimization for the plant Iotech/Moneco is presently building on a 50/50 cost shared basis with EMR.

A number of studies on gasification systems led to the establishment of the basic design parameters for the OMNIFUEL fluid-bed gasifier. An adaptation of this technology will be used in the Biosyn project for the production of synthesis gas from biomass.

A major study in the BDP program involved an evaluation of the state-of-the-art of various biomass conversion technologies including an assessment of the prospects for commercialization and the economics of conversion. The nine volume report provides much needed information on system configuration, equipment selection, capital and operating costs, material and energy balances and economic analyses to industry and government planners.

The BDP is supporting the development of the Heuristic gasifier which can be put into industrial use with little modification and which would have a normal life expectancy. Brunette Machine Works Limited, which is involved in the construction of the unit, has expressed an interest in obtaining an exclusive licence for manufacture of the gasifier upon completion of testing.

Work at Forintek Canada has resulted in the development of a combined enzymatic hydrolysis and fermentation process for wood cellulose which, coupled with steam explosion, represents a big step towards the commercial applicability of ethanol and industrial chemicals production from cellulose. This work has also identified potential commercial products for the other components of the lignocellulosic materials, lignin and hemicellulose, thereby improving the overall economic potential.

Program 5.4 - Fuels Processing: To develop improved technologies for upgrading synthetic crudes to high quality transportation fuels, particularly diesel and jet fuel.
To develop new technologies for the conversion of natural gas to transportation fuels.

Canada's traditional domestic production of light crude will be displaced increasingly by synthetic crudes and, eventually, coal-derived liquids. Much of these syncrudes will be unique to Canada. New refining technologies are needed. The federal government must be aware that these new technologies are available to Canadian refineries or must take steps to ensure that they are. This program has elements of industry support through a 50/50 contracting-out program and of long-term in-house research of, among other topics, catalyst development.

Distillate Treatment - CANMET (54101)

Several projects are pursued under this general heading, in the various sections of the Hydrocarbon Processing Research Laboratory (CANMET).

a) Oil Sands Distillates

The non-conventional crudes derived from the tar sands bitumen or heavy oils contain a higher proportion of aromatic hydrocarbons than conventional crudes. This characteristic impacts especially on the quality of middle distillates, that is on diesel and jet fuels. These aromatic hydrocarbons are hydrogenated (hydrotreated) during upgrading to saturated hydrocarbons (cycloparaffins) using conventional metal sulfide catalysts. The recently opened Shell Scotford refinery and Gulf's Edmonton refinery, which process oil sands bitumen, use conventional catalysts. These catalysts do not poison easily but are relatively inactive. For this reason, the hydrotreating takes place at high pressures.

Commercially available hydrotreating catalysts have been investigated at CANMET to understand some of the steric effects observed with them. As a result, a new more active catalyst was developed, which permits the hydrotreating reaction to take place at lower hydrogen pressures. A patent application for this catalyst was filed. This would be part of the package of upgrading technologies under development at CANMET.

b) Development of Catalysts for Co-processing Coal and Bitumen

In parallel to the work described under the Direct Liquefaction program, the Catalytic Hydroprocessing Section is investigating the effect of various catalysts/additives in coal/bitumen co-processing. A state-of-the-art review on co-processing work was completed as the first phase of this research.

c) Upgrading of Coal-derived Liquids

Coal liquefaction or pyrolysis technologies, such as H-Coal and Exxon Solvent Donor, produce a coal-derived liquid, whose composition depends on the coal used as starting material and the technology used to liquify it. Although the liquefaction characteristics of Canadian coals have been studied extensively, at home or abroad, there is at present a limited supply of coal liquids to study their upgrading. In general, these liquids have a high oxygen content. The oxygen is present as phenols, ethers, etc. It is known that among these oxygen containing compounds, the phenols are particularly undesirable, in that they poison most hydrotreating catalysts. One strategy for solving this problem is to remove these compounds by various means. A number of phenols has been identified in cool-derived liquids. The removal of these compounds was investigated by determining the hydrogenation parameters of model compounds. This work was applied to some naphthas obtained from coal-derived liquids, which permitted a complete removal of oxygen-containing compounds from this fraction.

d) Removal of Nitrogen Compounds by Adsorption

In response to a recommendation by the National Advisory Committee on Mining and Metallurgical Research (NACMMR), CANMET has investigated the removal of catalyst deactivating components, containing nitrogen, from various fractions of crude oil. Various adsorbents, such as zeolites and cation exchange resins, have been studied for removal of nitrogen containing compounds from naphthas. The resin A-15 (dry) was most effective followed by zeolite 13V. The adsorption of various model compounds was found to be a function of adsorbent cavity size and of the basicity of nitrogen compounds. Two patent applications are being prepared for the removal of nitrogenous compounds by:

a) zeolites with large cavities and with strong affinities for basic nitrogenous components; and
b) cation-exchange resins with functional groups of high acidity.

e) Membrane Separation of Aromatics and Saturates from Crude Oil Fractions

In response to a NACMMR recommendation, CANMET has studied the applicability of membranes to the segregation of various hydrocarbon types. In-house investigations showed that small pore membranes may be used to separate (saturated or aromatic) high quality fuel components from low quality fuel components, without a loss of hydrocarbons. Not only does this provide a high quality fuel for blending into the gasoline, diesel, or jet fuel pool, a reduced volume of low fuel quality stream is available for upgrading by conventional methods. Further, this upgrading can be of a severe nature since the higher quality components have already been safely removed. A patent application is being processed for the industrial application of some membranes for the separation of saturated and aromatic synthetic fuel components during upgrading to transportation fuels.

For the production of oxygenates, it was found that certain membranes do selectively exclude alcohols and allow permeation of ethers and hydrocarbons. Other membranes allow passage of alcohols but exclude ethers and hydrocarbons. A patent is being processed on the bases of these results.

Among other uses of membranes investigated in the laboratory, is their application in ultrafiltration and emulsion breaking (See Task 2).

CANMET 50/50 Contracts (54102)

This project was started in 1983 to encourage interested organizations to apply their resources and expertise to the development of fuel processing technologies. About 14 contracts were funded under this project over the past two years. Gulf Canada Limited, SNC Inc. and the Sandwell Beak Research Group were among the participants from the private sector.

Liquid Fuels from Natural Gas - CANMET (54201)

A technical and economic feasibility study on the electric arc process to convert natural gas to liquid fuels with acetylene as the intermediate, has been conducted by SNC Inc. under a cost-shared contract. The results from this preliminary study demonstrate significant potential for this route. A bench-scale fixed-bed reactor system has been constructed at CANMET for investigating the selective conversion of acetylene/ethylene to liquid fuels.

The direct conversion of natural gas to liquid fuels has been achieved in an argon plasma generated in a hollow cathode arc operating at 2000°K. A 60% yield of hydrocarbon product has been achieved to date. The investigation was carried out by University of Québec at Chicoutimi under contract.

Non-catalytic and catalytic oxidation of methane to methanol is being investigated at the University of Manitoba and at Waterloo University. A patent application has been submitted for a novel reactor design which has allowed these researchers to achieve very high methanol selectivity (80% methanol in oxidized products).

The Centre of Industrial Research of Québec (CRIQ) developed a new zeolite catalyst, based on boron and titanium, for the conversion of methanol to gasoline. This is a competitor to Mobil's ZSM-5 MTG catalyst. Two patents, one in Canada and one in the U.S., have been granted for this catalyst. The CRIQ catalyst was tested under a two-year contract from CANMET. Tests have shown that the CRIQ catalyst is more stable than Mobil's product (22 days between regenerations versus 15 days for Mobil's catalyst) and that it leads to higher yields of gasoline. The results of these tests have been presented to SOQUIP, Quebec's oil company, in a request for future financial support.

A fully automated high pressure system with a fixed bed reactor for producing diesel fuels from synthesis gas has been recently constructed at CANMET. The development and incorporation of several novel concepts, like the multizone computerized furnace with cooling and heating action or the high pressure on-line sampling capabilities, has resulted in a state-of-the-art facility.

A Fischer-Tropsch apparatus with four slurry reactors was constructed under contract at Queen's University in Kingston. This facility is designed for the fast testing and screening of novel synthesis catalysts and is available to all Canadian researchers.

Another study being carried out under contract concerns the production of intermediate olefins during Fischer-Tropsch reactions and further conversion with zeolite catalysts to gasoline hydrocarbons. Contracts with Dalhousie University, Ottawa University and Stearns-Catalytic Ltd. have been completed.

Liquid Fuels from Natural Gas - NRC (54202)

The Catalysis Group of NRC was involved in the study of direct conversion of methane to higher hydrocarbons. Catalysts have been screened and developed for the oxidative coupling of methane which yields mostly C-2 hydrocarbons, and a selectivity of up to 30% has been achieved on promoted bismuth oxide catalysts at 600-700°C. Such processes have been studied elsewhere, but the reaction temperatures were higher (700-900°C).

IREQ is studying, through a three-year contract from NRC, the alcohol synthesis from syngas. A series of catalysts has been developed to synthesize methanol from $CO_2 + H_2$ at efficiencies similar to or better than that of the conventional synthesis.

Program 5.5 - Fuel Use Program: **To establish the technical, economic and regulatory basis for the efficient, safe and timely deployment of new liquid fuels or wider boiling range fuels from synthetic crudes for use in transportation vehicles.**

Vehicle Safety and Alternative Fuel Transport Technology - TC (55102)

Chrysler Canada Ltd. prepared for TC's Transportation Development Centre of Montreal a critical state-of-the-art review of light duty propane vehicles technology, identifying opportunities for improvements and defining an R&D program aimed at optimizing propane engines and fuel system components. It was shown that optimization of propane vehicles could be best achieved through R&D at the OEM level. The following aspects were addressed:

- compression ratio
- carburation
- ignition
- valve timing and intake manifolds
- engine durability
- engine lubrication
- fuel storage and handling systems
- dual fuel systems
- low temperature operation
- propane fuel blends
- health and safety considerations

and R&D needs in each area were identified. This study led to a 1.5M$ contract jointly funded by EMR, the Ontario government and Chrysler Canada, for the optimization of propane vehicles (Phase II).

Space Fuel Gas Products Ltd. of Calgary has demonstrated, in a contract funded 90% by TC's Transportation Development Centre, the feasibility of converting a diesel engine to dual fuel (propane/diesel) operation. The converted engine was an International Harvester model 573B (260 HP) with the propane inducted into the engine with the air flow. The horsepower of the engine was not altered. Tests were conducted on an engine dynamometer. Partial substitution of diesel with propane resulted in lower air intake manifold and exhaust temperatures, and raised cylinder pressure (both peaks and the fluctuating component). However, the dual fuel mode of operation showed no cost advantage over diesel fuel only (the costs assumed were diesel 28.5 ¢/l., propane 18.5 ¢/l.). The report recommended a propane/diesel (weight basis) ratio of 0.25, which would not adversely affect the life of the engine. This corresponds to a 20% reduction in diesel fuel consumption. Two cycle diesel engines are not recommended for such conversions.

In the natural gas area a major review of safety of storing, handling and dispensing natural gas in the road sector has been completed by Chemetics International Co.; some 16 recommendations have been put forward and follow-up efforts are being pursued. In addition, work has begun with the Canadian Coast Guard to examine the safety aspects and ultimately test marine applications using natural gas (BC Ferry Co. and EMR are involved in this process). Finally, some exploratory research has been launched to examine the economic and operating realities of using natural gas in the rail sector (this has considerable carrier and industry interest and complements a proposed small demonstration of an LNG locomotive on BC Hydro property).

A major R&D effort is underway on neat methanol in spark ignition engines. The work is carried out at Transport Canada's Motor Vehicle Test Centre in Blainville, Québec. The "neat" methanol test vehicles include five Ford Escorts (four carboretted and one fuel injected), one Volkswagen GTI and a Toyota Camry. Baseline date is provided from two Ford Escorts (fueled by gasoline) and a Chevette (fueled by diesel). The cold start work is complete and the results indicate that considerable starting difficulty is experienced at temperatures of - 22°C and below; however, considerable variations exist depending upon fuel formulations (5 tested) and engine technologies. Current work is concentrating on emissions (including degradation over time), driveability and long term engine wear. Methanol safety R&D has led to the physical property determination (9 fuels) in terms of flammability, luminosity etc; various fire/explosion fighting agencies and provincial representatives will be participating in next phase risk assessment/identification work.

Future Diesel and Gas Turbine Fuels - NRC (55203)

Energy R&D Panel funds have contributed in part to build up engine and fuel test facilities in the Division of Mechanical Engineering of NRC. The Panel's contribution to this installation was about 1M$. The facility is a state-of-the-art laboratory which was used in cooperative projects with the Canadian engine and fuel industries and to carry out the studies described below.

Canada is unique in the world in that it has two plants (Suncor and Syncrude) producing synthetic crude from tar sands bitumen. The present capacity of these plants is 183,000 b/d, or about 10% of total crude deliveries to refineries. In 1980 it was forecast that at least two large tar sands extraction plants would be built and synthetic crude would supply 24% of Canadian needs in 1990 and 49% in year 2000. Subsequently, the two large plants were shelved and 1984 projections for synthetic crude penetration are 14% (in 1990) and 34% (in 2000).

Although the tar sands synthetic crude contains a higher proportion of middle distillate, it unfortunately has more naphthenic and aromatic components, which make it less suitable for diesel and gas turbine fuel production.

The other Canadian development affecting diesel quality is the financial encouragement given to switching home heating from type 2 fuel oil to natural gas. Also, the switching of a large share of industrial users from heavy residual fuel to natural gas has taken place.

The major oil companies were canvassed in 1980 with regard to the quality of diesel fuel to be available in sufficient quantities in 1990 without major capital and operating expenditure increases for upgrading purposes. The consensus at that time, with demand forecasts based on 1981 NEB data, yielded the "Canadian 1990 Diesel Fuel" proposed specifications. About 100,000 gallons of such a blend fuel was prepared for NRC, containing 22% cat-cracked cycle oil, 39% tar sands material and the balance from conventional Alberta crude. The specifications of the "1990 diesel" and the properties of the actual blend are given in Table I, together with present specification for diesel No.2 fuel. A 1983 survey of diesel quality reached the consensus that the 1990 fuel specifications relaxation would not be required until after year 2000. The new 1990 or "Intermediate" fuel forecast is also given in Table I. A few drums of this type of fuel have been blended for NRC, containing 24% hydrotreated light cat-cracked cycle oil, 12% tar sands material and the remainder from conventional Alberta crude.

Because of modifications to two Edmonton refineries and the opening of Shell's Scotford Refinery in 1984 (built specifically to process synthetic crude only), it seems likely that the bulk of tar sands synthetic crude will be processed in Western Canada (in Alberta with the remainder at Sarnia) in the 1986-95 period. It may therefore be necessary to produce two blends, a Western blend from synthetic and conventional crude, and an Eastern blend of conventional plus cat-cracked cycle oil. Theoretically, the Eastern blend would be more difficult to combust because it is likely to contain more condensed aromatics.

Table I. Diesel Fuel Specifications

	Present Specification CAN2-3.6-M83	Future Fuels 1990		"Intermediate"
Property	Type B	Proposed	Actual Blend	
Flash Point, °C	40 min.	38-42	60	69
Cloud Point, °C	as required	-	-10	-
Pour Point, °C	as required	-	-36	-27
Distillation, 90% recovered, °C	360 max.	360-370	354	303
Sulphur, %	0.7 max.	0.7 max	0.5	0.4
Carbon Residue (Ramsbottom) on 10% Bottoms, %	0.2 max.	0.2 max.	0.2	-
Cetane Number	40 min.	34-36	35	38
Hydrogen, %	-	-	12.2	12.3
Hydrocarbon type % vol. by D1319				
Aromatics	-	-	48.1	40.8
Saturates	-	-	51.2	58.5

Engine investigations on future fuels

a) RAILROAD ENGINES - the two major Canadian railways have operated successfully in Alberta on tar sands gas oil sidestream for many years. This fuel is a heavy kerosene with a cetane number around 30. CN Rail have also been operating successfully on heating fuels containing cat-cracked material (cetane numbers 30-45) in the summer in Eastern Canada and winter operation is planned when all locomotives are equipped with hot wells to cope with the higher cloud points. Experiments with blends of residual fuel/diesel in main line and switcher locomotives were concluded because it was found that the upper limit of residual fuel which did not form deposits at idle was 10% and this was not economically attractive.

Combustion tests were also conducted by Bombardier at the Naval Engineering Test Establishment in Montreal. These results are detailed in project 55201.

b) TRUCK ENGINES - since the large railroad engines appear to work well on fuels with cetane numbers as low as 30 it was felt the next step was to investigate the actual fuel requirements of the 300-400 HP class of diesel engines used in Class 7 and 8 trucks. The engines used up to the present have been a Detroit Diesel Allison (DDA) 3-71 at the National Research Council (see below), a DDA 6V-53T engine at University of Ottawa (under a Department of National Defence contract), a DDA 6V92TT engine at Gulf Research, Sheridan Park (under a contract from NRC) and a single cylinder Deutz F1L 511D air cooled engine at the Defence Research Establishment, Ottawa. All of these engines show an increase in ignition delay of 1-2 crank angle degrees when the 1990 fuel is compared to No. 2-D fuel. There is also a corresponding increase in the maximum rates of pressure rise but maximum cylinder pressures show little change. The engine manufacturers do not consider these increases to be too serious, therefore, further long term runs are planned to indicate deposit or wear problems.

A Cummins 400 HP turbocharged engine with one fully instrumented cylinder has just been installed at the National Research Council and a variety of fuels will be investigated in a joint program with Cummins.

NRC investigated the effect of low cetane number on other engines as well. Four diesel fuels with cetane numbers of 40, 37, 35 and 26 have been tested in a fully instrumented Detroit Diesel Allison 3-71 engine using the standard N65 injectors. The 35 and 37 cetane number fuels were the "1990 diesel" and the "Intermediate" fuel described before. The engine is a three cylinder with a total displacement of 3.49 litres, rated at 100 BHP. No difficulties were encountered in operating the engine for periods of twenty hours on these fuels. The 26 cetane number fuel increased audible engine noise and posed startability problems at ambient temperature. A non-linear relationship between ignition delay and cetane number was observed for these fuels. Engine durability, deposits and low temperature operability tests are planned.

The Fuels and Lubricants Laboratory of NRC undertook a comprehensive investigation of correlations used to estimate cetane numbers. For the first time, carbon groups which have a dominant effect on ignition quality were specified. Based on this information, a simple and effective method was presented to determine these carbon types by ^{1}H NMR spectropy, and to predict cetane numbers for diesel fuels. A total of 134 conventional and future diesel fuels were analysed by this method, which provided a much better accuracy of predicted cetane numbers than cetane number measurements on standard engines.

The experimental results and experience gained with low cetane number fuel will be reviewed by the Diesel Fuel Panel of the Middle Distillate Subcommittee of the Canadian General Standards Board Committee on Petroleum (with membership from Cummings, Detroit Diesel, John Deere, CN and CP, DND, NRC) and used to set future diesel fuel standards.

Combustion Studies in Diesel Engines and Properties of Conventional and Tar Sands Derived Aircraft Gas Turbine Fuels - DND (55201)

University of Laval has investigated under contract the effect of fuel properties on combustion parameters in a gas turbine. Representative tar sands fuels as well as a series of synthesized fuels have been studied and the results were used to develop correlations between specific fuel properties and carbon formation, oxides of nitrogen formation, combustion efficiencies, combustion liner temperatures and ignition behaviour. Such correlations will assist in predicting the behaviour of future low quality gas turbine fuels and determining the consequences of relaxing the present specifications for gas turbine fuels.

University of Ottawa has characterized the behaviour of a two stroke, turbocharged medium speed diesel engine (GM 6V53T) when operated on tar sands (off-specification) derived fuels. The work to date includes performance/combustion behaviour of four fuels (including the NRC 1990 diesel fuel), thermodynamic model correlation with experimental data, scavenging/compression-expansion multi-dimensional analyses and the experimental measurement of the flow field, during scavenging, in the engine. Full load and part load brake, indicated and combustion characteristic performance curves plus fuel-to-fuel comparison plots of each parameter have been generated. The most informative presentation format was found to be parameter maps contoured over the complete operating range of the engine. Concern exists over the compatibility of the off-specification fuels due to high pressure rates and gas vibrations which occur over large operating ranges of the engine. Thus, the engine is being instrumented with vibration and acoustic monitors so as to measure the physical response of the engine versus combustion pressure rate.

Bombardier Inc. investigated for DND the effect of degraded quality diesel fuels on the performance and operability of medium speed diesel engines. Seven different fuels were studied: conventional ASTM No.2-D diesel (reference fuel) and various blends with heavy atmospheric gas oil (end point 400°C), conventional Western Canadian crude, tar sands crude, No. 2 and 6 heating fuel, including NRC's "1990" diesel fuel. The cetane number of these

fuels was between 29.4 and 46.8 and the aromatics between 28.6% and 55.7%. The test engine was a 12 cylinder Bombardier 251 engine (9" bore x 10 1/2" stroke) rated at 250 BHP/cylinder at 1100 RPM. All tests conducted were of basic performance type, with no more than 16 hours of engine operation on each fuel.

No major engine operational difficulties were encountered throughout the testing of the degraded fuels. Some combustion data, however, indicated that possible long term durability shortcomings may exist. In comparison to the reference fuel, the combustion delay was longer for all test fuels, except the No. 2-D diesel having a high final boiling point. High rates of pressure rise, increased specific fuel consumption and high maximum cylinder pressures were also observed.

In Phase II of the Bombardier investigation, durability tests were conducted including 500 hour runs with the "1990" diesel fuel and with a 30:70, 2-D:6-D fuel blend. No problems were encountered with the "1990" fuel but accelerated valve wear and accumulation of deposits in the exhaust system occurred during operation with the 2-D:6-D blend. Since North American medium speed diesel engines are designed primarily to consume conventional ASTM No. 2-D fuel, this new information will permit engine/combustion system modification to suit a range of future Canadian and world fuel options.

Coal Slurries and Diesel Fuel - NRC (55204)

The coal slurry test program (28% Devco coal slurry in diesel fuel) has found unacceptable wear on the pump plungers, extensive deformation of nozzle valve seats and serious erosion of the nozzle holes. The extensive redesign and development required to accommodate a coal slurry system that would displace only 25% of diesel fuel was considered uneconomical and this program was terminated.

Coal Fired Stirling Engines - TC (55207)

In the rail sector the R&D has been confined primarily to two areas, namely coal-fired Stirling engine and single cylinder research; following substantial model and bench testing it was proposed to convert an existing Bombardier MLW 251 (3000 HP) 4 stroke diesel engine into an air operated Stirling engine. However, substantial difficulties with seals on moving parts in an engine of this size led to a decision to not pursue any further work in this specific area.

Combustion Technology and Specifications for Alternative Fuels - EMR/CNP (55209)

Federal concerns regarding the quality of future diesel fuels have resulted in joint participation by the Canadian government, Canadian oil refiners and U.S. truck engine manufacturers who have agreed, together with the Canadian trucking industry, to evaluate low-cetane diesel fuels in low temperature operations. Such fuels are the types anticipated to be available at the Canadian fuel pumps in 1995-2000 as a result of increased bitumen/heavy oil feedstocks. The Industry-Agreed Test Program is now ready for the evaluation of synthesized fuel stocks in single-cylinder and multi-cylinder engines and in vehicle field trials. This is ongoing with the participation of industries concerned. This is a necessary step leading to fuel specifications (government) and engine design (industry) for these future fuels, particularly in the Canadian winter climate.

Low/Medium BTU Gas Facility - NRC (55205)

The Gas Dynamics Laboratory has installed a gas turbine (manufactured by Westinghouse) to conduct combustion studies. This is a state-of-the-art turbine, electronically controlled, fully instrumented (including laser to study droplet size) and having an inside quartz jacket for observation. Some of the funds for this facility were received from Westinghouse. Investigations were carried out for this turbine manufacturer using a low/medium BTU gas (about 25% of the BTU in this mixture is given by natural gas). This work led to engine changes in the Westinghouse turbine, which would permit the use of a degraded fuel. Other studies were conducted for Rolls Royce on the RB211 engine.

R&D in CNG in Transportation - EMR/CNP (55210)

This is carried out at the B.C. Research Council within a $1.6 million contract over three years let by EMR (the contract received TB approval on December 9, 1983 and was signed in January 1984). Five discrete areas are supported. The work is guided by a steering committee with membership from original equipment manufacturers (Chrysler, Ford, General Motors), gas distributors (e.g., Gaz Metropolitain), and provincial and federal governments.

Basic Research, done mostly at U.B.C., is by a world-class centre on methane combustion. Four PhDs have graduated from this group. Major capital equipment for this laboratory, such as a Ricardo Hydra test engine, was purchased by the federal government.

BCRC is conducting product evaluation and improvement studies, and its facilities are available, on contract, to the private sector. One of BCRC's research studies concluded that the pre-cylinder venturi was not adequate; the conversion kit manufacturers are now using this information to improve their product. BCRC is also looking at CNG in diesel engines and CNG in two-stroke engines on a shared-cost basis for commercial clients.

With respect to safety, work with the Canadian Gas Association's Safety Council has led to refueling station standards and also to standards for vehicle conversions. Work has started, in part in response to original equipment manfuacturers' requests, on standards for production-line CNG fuel systems. The BCRC facility has discovered a flaw in the "burst disk" pressure release tank fixtures and is preparing an appropriate standard.

Compressors are a key component of CNG use. BCRC has a program of testing, design and standards. In particular, they are developing an on-board compressor versatile enough to fill a tank from the 20 psi domestic distribution lines or from the 100 psi mains.

To promote technology transfer, BCRC has computer-catalogued more than 2500 reports on methane in vehicles. This is now an on-line information centre with free access for industry and universities.

The natural gas/air mixture has a slower flame speed, is harder to ignite and has a longer ignition delay than the corresponding gasoline/air mixture. For this reason, spark ignition engines require a greater ignition advance for natural gas operation than for gasoline operation. The advance required for CNG operation causes unacceptable knock during gasoline operation; the advance required for gasoline causes high exhaust temperatures and a loss of efficiency during CNG operation. Because of this, most CNG conversion kits contain a "black box", a device for varying the ignition timing as a function of the fuel in use.

The B.C. Research Council evaluated two commercially available timing devices, a Dual Curve Ignition device made by Autotronic Controls Corp. of El Paso, Texas, and a Digital Spark Ignition system manufactured by Tri-Fuels Inc. of Baton Rouge, Louisiana, and compared them against the minimum spark advance for best torque (MBT) timing curve determined for a 2.8 litre Chevrolet V6 engine operating on natural gas. Neither device gave a timing curve on CNG similar to the MBT curve. In the 2000-3000 RPM range, the curves were fairly close, although above this engine speed range, the timing devices provided less ignition advance than the engine required. This showed up in slightly reduced power and slightly increased brake specific fuel consumption. The Dual Curve ignition device was considered the better of the two devices tested.

B.C. Research Council tested seven CNG conversion kits on three vehicles, a Ford F-250 truck, a Chevrolet S-10 truck and a Dodge 600 passenger car. Power, fuel consumption and air/fuel ratio were measured as functions of speed and load. All conversion kits produced approximately 20% less power than the unconverted vehicle operating on gasoline. The differences in power and fuel consumption were most pronounced in the Ford, the test vehicle with the largest engine (when the gas flow requirements of the engine are close to the maximum flow rate of the CNG conversion system). This information is being used in second-generation equipment development.

The spark plug gap is another parameter which affects engine performance. This was investigated on a Chevrolet S-10, 2.8 litre V6 test vehicle, equipped with a high energy ignition system, operating on natural gas. Four spark plug gap sizes (0.75, 1.12, 1.5 and 2.0 mm) were tested both on a chassis dynamometer and over the road. For engine speeds up to 4000 RPM there is no difference in output power or fuel consumption for the four spark plug gaps. Above 4000 RPM the power drops off significantly for a gap of 2mm, due to severe vehicle misfire. The spark plug of 1.5 mm offered the best drivability.

The crashworthiness of various CNG fuel system components (high or low pressure tubing, pressure regulator and gas mixers) was investigated at the B.C. Research Council. Results indicated that most components and practices employed at the present time are satisfactory. The pressure regulator and refueling probe are, however, susceptible to failures because of their location at the front of the vehicle. Recommendations were made to locate these components on the firewall, or installing a back check valve on the fire wall (for the case of the refueling probe).

An analysis conducted by the B.C. Research Council and the IBI Group concluded that there is a significant market for conversion of heavy diesel trucks (Group 6, 7 and 8) to CNG in lower mainland B.C. and in Southern Ontario. The most attractive group of trucks for conversion are the group 6 and 7 vehicles confined to a major urban centre. A review of the technical information of dual-fueled CNG/diesel engine conversion kits performed by the same group, reached the conclusion that present kits are not at a high level of technical sophistication and do not optimize the operation of the engine under varying speed/load conditions encountered in a truck engine. There is a requirement to develop "second generation" conversion systems, to be tackled in Phase II of this study.

The Department of Energy, Mines and Resources co-sponsored with the Government of Ontario, the Canadian Oxygenated Fuels Association, Celanese Canada Inc. and Mohawk Oil Co., the Sixth International Symposium on Alcohol Fuels Technology, held between May 21-25, 1984 in Ottawa. The symposium, attended by 463 delegates from 30 countries, included the presentation of 150 technical papers and an exhibition of alcohol-fueled vehicles. The sessions included also a review of alcohol fuel developments in eleven countries and gave an excellent opportunity to exchange information and strengthen collaboration between participating countries in alcohol fuel technologies.

The Industrial Technology Centre of the Manitoba Research Council prepared, under contract from TED, a world-wide review of fleet tests using methanol/gasoline blends. The report covers the 1977-1985 period and includes the results of 18 testing programs in seven countries. In Canada, fleet trials were performed by: Canadian Methanol Canadien, Celanese Canada, Ontario Ministry of Transportation and Communications and the Manitoba Research Council.

In a report prepared by the Bureau of Management Consulting, the major issues impacting on the scale, scope and timing of methanol blends were identified and analysed. The issues fall into three major areas: technical; cost and price; and institutional, regulatory and marketing. The technical issues revolve around the incomplete knowledge of the effect of methanol and co-solvents in the vehicle system fuel distribution system and the environment. The reason for financial concerns are that significant economic analyses of the blend market, the cost of distribution and the net benefit have not yet been undertaken. The institutional, regulatory and marketing issues will not in themselves constrain the implementation of blends except for the timing of the United States activity. The major conclusions of the report are that blends will not penetrate in any significant way the fuel pool without financial support or legislative intervention, market penetration before 1987 is unrealistic, and that blending of the gasoline will occur at the refinery.

There are four policy directions which can be followed for future methanol blends implementation: legislated implementation, funded implementation, phased implementation and the "laissez faire" option. Based on the analysis performed, the option recommended is the phased implementation of the 5% methanol blend (M5), through a "blend" of legislative, fiscal and cooperative actions.

Draft specifications for oxygenated fuel blends have been developed: the maximum oxygen content (alcohol and co-solvent) in unleaded gasoline is proposed to be 3.7% (by weight), with the methanol content not exceeding 5% (by volume).

The Industrial Technology Centre of the Manitoba Research Council developed, under contract from TED, a method for determining aldehydes in automobile exhaust. Aldehydes (and ketones) are of interest especially for alcohol fueled vehicles. The method, which uses 2,4-dinitrophenyl hydrazine (DNPH) as reagent and detection by high-performance liquid chromatography, is simple and rapid and permits detection of aldehydes at the part-per-billion level. Among the aldehydes detected are formaldehyde, acetaldehyde, benzaldehyde, etc.

The Demonstration of the Use of Methanol in Large Engines (Project MILE) contract, awarded to Sypher:Mueller International Inc. as prime contractor is an 8M$ government/industry cost-shared study on methanol use in medium and heavy duty spark ignition engines and diesel engines. The industry/institutional participants include methanol suppliers and distributors (Alberta Gas Chemicals Ltd., Celanese Inc., Ocelot Chemicals, Petro-Canada, Shell Canada Ltd., and Gulf Canada Ltd.), engine manufacturers (Detroit Diesel Allison division of General Motors of Canada, Ford, Cummings and Diamler Benz), fleet operators (Cities of Winnipeg and Medicine Hat, Trimac, Voyageur, CN/CP, Boyd Transport, ICL, and B.C. Rail) and fleet infrastructure and information dissemination organizations (Midwest Detroit Diesel Ltd., Canadian Trucking Association, Road and Transport Association of Canada, Fleet Maintenance Council, the Ontario Center for Automotive Parts Technologies) and possibly the provincial governments of Manitoba, B.C., Alberta and Ontario. The contract was awarded in May 1985 and there are no accomplishments yet.

Canada is participating in the International Energy Agency Alcohol Fuels Agreement together with Sweden, U.S. and New Zealand. Japan has recently joined this Agreement. Under the Annex I of this Agreement, Sweden has prepared, with input from the other participating countries, a comprehensive review on alcohol fuels. This report will be issued later in 1985. Other annexes are presently being discussed and Canada is considering Project MILE as a possible contribution to an annex dealing with methanol in large engines.

Program 5.6 - Hydrogen and Energy Storage: To develop hydrogen production (561); utilization (562); and energy storage (563) technologies.

A highlight of the 1984-85 fiscal year was the 5th World Hydrogen Energy Conference held in Toronto and sponsored by the National Research Council through the Hydrogen and Energy Storage Program. The National Organizing Committee of the conference included representation from all sectors of the Canadian hydrogen community. Organization of this conference proved to be an ideal opportunity for addressing the non-technical goals of this program which includes mediation and coordination of the related Canadian activities and interests into a cohesive and integrated national strength. A unique opportunity was provided to the dispersed Canadian hydrogen community to meet and exchange ideas with an international hydrogen community represented by delegates from thirty-one nations. The inaugural meeting of the Canadian Hydrogen Safety committee also took place at the conference; it has strong industry participation.

Hydrogen Production Subprogram (Hydrogen Systems) (561)

With respect to hydrogen production, the major emphasis is the optimization of hydrogen production by electrolysis of water, with a special emphasis on cost reduction by improving the efficiency of electrical energy use and capital utilization.

Hydrogen Production by Electrolysis - NRC (56101)

Federal research (in-house and contracted) has helped push Canada to the forefront of modern electrolytic production of hydrogen. Much of this has been through support of the Noranda/Electrolyser consortium, accompanied by demonstrations at Hydro Quebec. The Electrolyser Corporation, with worldwide sales, is the only large producer to promote the unipolar design. Conversion efficiencies of 75% are attained, as good as that of any reliable commercial electrolyser in the world. This significant industrial development means that Canada now has a good alternative to natural gas as a source of hydrogen for bitumen/heavy oil upgrading and coal conversion or other applications.

The technology developed by the Electrolyser Corporation will be demonstrated in an advanced hydrogen production plant, to be built at Bécancour, Québec. The 25M$ plant will be owned by Air Liquide and Hydro Québec and will produce ten tonnes of liquid hydrogen per day. A contribution from TED will support research-related capital expenditures for the plant. Other federal funds were announced on April 12, 1985, and originate from the Industrial and Regional Development Program (IRDP) and Energy, Mines and Resources Development Funds.

More specifically, some accomplishments of the hydrogen production program are:

Identification of promising ceramics as potential anode catalysts; they are much cheaper than noble and semi-noble metals, which are known to be most suited to the technical requirements. Full size electrodes will be made and tested in the Noranda test cells.

Improved separators, necessary for the harsh environment of strong alkaline solutions in advanced electrolysis, have resulted from IEA program activities and Canadian manufacturers now have access to this technology.

The program has shown that aromatic ionomers (alkoxycarbonyl substituted phenylated polyphenylenes) can be produced which have the necessary technical characteristics for ion conducting solid polymer electrolytes (SPE). Scale up of various steps in the polymer production process have begun.

Hydrogen Utilization Subprogram (562)

This subprogram includes the storage, transmission, distribution and end-use of hydrogen. Work is at an early stage in this subprogram. Program definition has been completed and implementation of the initial phase is underway. This is a long-term activity. Accomplishments at this early stage are mostly related to identification of the scope and content of future activities rather than to immediate application.

Hydrogen/Air Fuel Cell - CANMET (56202)

The objective of this project is to develop a solid electrolyte hydrogen fuel cell. This includes both the development of the electrolyte and electrode. A method for the preparation of sodium beta-alumina, a precursor for hydronium beta-alumina - a two dimensional hydrogen ion conductor, was developed based on a commercially viable sintering schedule. This method yields a high density material (greater than 97% of theoretical) with a high concentration of the desired high conductivity phase (this is expressed by the parameter f(beta) which should be below 0.45; the material prepared had f(beta) below 0.3, coupled with high density).

Among the three dimensional conductors investigated are zirpsios, gasicons and yasicons (the latter two by contract at McMaster University, funded by CANMET). Zirpsios is produced from the Na_2O - ZrO_2 - P_2O_5 - SiO_2 system. A total of 18 compositions of this system were investigated, which produce essentially a material of theoretical density with a very high ionic conductivity. The sodium form, which may be exchanged to a hydronium state, was used successfully in a hydrogen/air fuel cell.

Reactive gasicons and yasicons powders were readily produced by a simple spray drying process. These powders can be processed to high density and can be ion exchanged to a highly conductive hydronium ion form. Patent applications on behalf of the Crown were filed for these processes.

Because of the possibility of using these electrolytes at temperatures up to about 275°C (beta-alumina) at close to atmospheric pressure or over 400°C under high pressure (to suppress dehydration of the electrolyte), it should be possible to obtain good electrode/catalyst kinetics without using a noble metal or alloy. Hence, efforts are being expended to both develop and characterize electrode systems.

Electrode selection criteria of chemical and mechanical stability, electrochemical activity and low cost have suggested Ni, $LaNi_5$ and the perovskite $LaCoO_3$ as candidate materials.

Queen's University has examined under contract (co-funded by NRC and CANMET) a number of electrode material candidates and has narrowed the field down to LaNiO, $LaNi_5$, $LaCoO_3$, some perovskites and TiO_2-based materials. They are currently developing methods for their deposition which include painting and decomposing a sol, sputtering, and plasma spraying. Preliminary studies have demonstrated that well bonded electrodes can be produced by all three techniques.

Hydrogen Storage - Large Scale - NRC (56203)

A techno-economic analysis of the methods of storing gaseous or liquid hydrogen in large quantities has been carried out by Canatom Inc. It includes above ground storage in pressure vessels or cryogenic containers and underground storage in rock caverns, salt domes or permeable rock. This study, now a major reference report, will lead to the selection of particular methods for more detailed study and potential application.

Hydrogen Storage - Small Scale - NRC (56203)

The Ontario Research Foundation has been working under contract on storing hydrogen in glass microcapsules. Such capsules can contain high internal pressures and yet be kept in a vessel not, itself, built for high pressures. Microballoons and hollow fibres have been studied. A charge/discharge system with capability to 6000 psi and 300°C was designed and constructed. Although non-optimized hydrogen storage densities of greater than 2% were observed, this technique has proved to be expensive. Applications related to gas separation are now being considered.

Hydrides - NRC (56203)

Gaseous or liquid storage of hydrogen has shortcomings, although they are the preferred method given current technology. An alternative is to react hydrogen reversibly with certain metal alloys to give solid compounds containing up to 5% by weight of hydrogen. The objective of this project is to obtain reliable and accurate data on these alloy hydride systems. Alloys studied to date include Mg_2Ni, FeTi, FeTiO, $LaNi_5$ and $CaNi_5$. Magnesium alloys (attractive because of magnesium's light weight) are not suitable for hydrogen storage because of the extremely slow speed of the reaction with hydrogen. In-house work at NRC is directed toward the cause and eventual control of such process kinetics.

Liquid Hydrogen - Carriers - NRC (56203)

One means of carrying hydrogen can be to combine it to form a liquid (such as methanol or ammonia), and then decompose it just before combustion in a fuel cell or internal combustion engine (ICE). Advantages of this method could include increased efficiency and lower pollution. A study (Phase I) has been done by Engelhard Industries of Canada Ltd. and the Ontario Research Foundation on on-board hydrogen generation from liquid carriers. Findings of this study suggest that development to reach the automotive application requirements is feasible and could provide a considerable fuel saving over liquid methanol direct fueling. The major thrust was for an ICE application. A fuel cell/battery powered city bus system was selected for analysis with steam reformed methanol fueling a phosphoric acid fuel cell which, in turn, charges a battery for high power demands. The work to date encourages further research on this promising long term fuel system.

Experimental Development of an Ammonia Fueled Engine - NRC (56203)

Associated with the liquid hydrogen-carriers, this three-phase project examined the operation of a diesel engine running on ammonia (NH_3) fuel. The Detroit Diesel Allison "Fuel Pincher" engine (8.2 litre) has been selected (Phase I) as the most suitable for conversion. A research and development plan (Phase II) was completed and included work on a single cylinder version of the above engine made available by Midwest Detroit Diesel (General Motors). Phase II included the ammonia carburetor and fuel system development, an ammonia dissociator development and emission studies. The thermal efficiency of the ammonia fueled engine (48% at an 18:1 compression ratio) exceeded expectations. Tests conducted using hydrogen addition did not provide increased power output, however a slightly higher (50%) thermal efficiency was achieved. No decision has been taken about Phase III yet.

A Micro Ammonia Plant for Hydrogen Energy Storage in Remote Locations - NRC (56203)

A contract has been awarded to Associated Kellog Ltd. to assess the feasibility and economics of small scale ammonia production, less than one ton/day. This is a remote community targetted application where there is a variable or intermittent primary energy source such as wind.

Safety and Embrittlement - NRC (56203)

In anticipation of hydrogen as a significant energy currency, safety studies should parallel the development of use technologies. Several projects are under way.

Hydrogen Safety - NRC (56203)

A contract let to Chemetics International Limited has used "Hazard and Operability" study methods as applied in industrial installations to identify, analyze and make recommendations regarding hydrogen safety. The contractor identified safety problems and also concluded that there appears to be no fundamental obstacle to the use of hydrogen as a transportation fuel, and that liquid hydrogen appeared to be the preferred storage form. Also as a result of the report's recommendations, a National Hydrogen Safety Committee has been formed.

Ammonia Safety - NRC (56203)

Ammonia is a potential carrier for hydrogen - both as a fuel and as a hydrogen storage medium since it can be readily decomposed. Chemetics International Company has concluded that (i) although there is no economic incentive for ammonia use, a shortage of carbon-based fuels could change this, and (ii) a safety assessment showed that there is a trade-off between the toxicity of ammonia and the flammability of petroleum. The report is a useful reference in judging the time and conditions when ammonia may seriously be regarded as an alternative transportation fuel.

Natural Gas Fuel Cell - NRC (56203)

A program has been established to test and evaluate existing fuel cells. A 40 kW United Technologies phosphoric acid fuel cell has been purchased. It will operate on natural gas which is reformed to produce hydrogen prior to entering the fuel cell stack. Since the feedstock is natural gas, application of this type of power plant is not dependent on the future availability of low cost hydrogen derived from water, and is a logical first step in the development of a national fuel cell program. The fuel cell is presently being tested at a gas/electric utility.

Energy Storage Subprogram (563)

The specific objectives of this subprogram include the assessment and development of batteries (for stationary or mobile applications), the development of flywheels and the assessment and development of electric vehicles. Given the long term nature of the research involved and the available resources, only specific aspects could be tackled in each category.

Electric Vehicle R&D - EMR (56301)

Following active participation by the Transportation Energy Division (EMR) in the Ontario government's Electric Vehicle Task Force (1982), a project was launched to assess developments in electric vehicles in Canadian conditions. This is in keeping with the Task Force report which recommended that such an assessment would bridge the time until high energy density battery designs are available for Canadian industrial participation. The Ontario government and EMR are jointly supporting the purchase and conversion of three Canadian-built Chrysler T115 vans to electric traction using the most advanced control technology. These will be tested in Canadian climatic conditions, initially providing baseline information on state-of-the-art lead acid batteries, followed by prototype sodium sulphur high energy density batteries. The Ontario Centre for Automotive Parts Technology (Saint Catherines, Ontario) is participating in this work, thus ensuring technology transfer to industry.

Electric Vehicle R&D - TC (56302)

NRC/IRAP has supported Moli Energy Limited of British Columbia in the development of high-density, ambient temperature, molybdenum/lithium batteries and thus contributed to the company's decision to produce "C" cell batteries for large-volume commercial sale. The outlook is so promising that the federal and provincial governments are providing about $20 million for production facilities at Kamloops (molybdenum preparation) and Maple Ridge (battery fabrication) and for further research at Burnaby. Within this program, Transport Canada's Transportation Development Centre, Montreal, has funded research on scale-up of this battery. Good results have been achieved on upscaling to over 20 times the size of the "C" cell. This technology may lead to a practical battery for electric vehicles.

Energy Storage - NRC (56303)

1) Electrochemical storage (batteries). Because of funding constraints efforts in the battery development area are concentrated on one system, the high temperature lithium - iron sulfide (or Li/FeS) battery. Hydro-Québec has developed engineering scale laboratory cells. Several cells were produced at IREQ and evaluated at the Defence Research Establishment, Ottawa (DREO). Energy densities of approximately 50 Wh/kg were achieved. A similar cell is being developed, under the management of the Argonne National Laboratories in the U.S., which shows performance characteristics comparable to the cell developed in Canada. The optimization of Li/FeS cells for commercial production is being examined by Electrofuel Manufacturing Co. A prototype cell fabrication facility is under construction and will deliver a significant number of cells for testing in 1985. The current cells have greatly improved capabilities and very considerable cost reduction.

   Of the several separator materials investigated for the Li/FeS cell, boron nitride was found to be preferred because it is electrically insulating, has a high corrosion resistance and may be fabricated as a felt. The development of less costly and technically superior boron nitride felts was undertaken by Blue Mountain Pottery and sub-contracted to the Ontario Research Foundation. This activity will phase-in with the cell fabrication program.

ii) Mechanical Storage. The flywheel is a convenient load levelling storage device capable of storing deceleration energy and delivering high power densities (for acceleration). Canada has access to U.S. federal activities through an exchange agreement with the lead agency, the Lawrence Livermore Laboratories. The design of fibre composite flywheels was examined through a contract with the University of Ottawa. The work includes the design, construction and testing of 1 kWh flywheels suitable for vehicle applications.

   Optimization of fibre composite flywheel designs has reduced the options to four, and one of these has been proven by fabrication and testing. The most appropriate way to transfer this technology to industry is being assessed. As an outcome of this project, a world-class expertise in flywheels and composite materials has been created, and new outlets for this technology are already being explored in the fabrication of high pressure tanks.

Program 5.7 - Environment: **To identify the potential environmental and health hazards associated with the study, production and use of new liquid fuels and to develop technologies or recommend regulatory measures to minimize or eliminate the identified hazards.**

The environmental importance assigned to any fuel or process was determined by weighting a number of factors such as the likelihood of its commercial development, the hazardous compounds in the effluents or wastes associated with its production, the degree of understanding of environmental risks associated with these compounds and the technologies available to control their release in the working place or environment. The following priorities were established within the program:

High	Medium	Low
- wide boiling range distillate fuels	- ethanol	- propane
- methanol	- wood gasification	- methane
- coal/bitumen co-processing	- higher alcohols	- hydrogen
- coal liquefaction	- coal gasification	

IEC Beak Consultants Ltd. has reviewed (for HWC) in fiscal year 1981-82 the potential health hazards to workers involved in the production of synthetic fuels from coal and biomass. In fiscal year 1982-83 two contracts were let by HWC to IEC Beak Consultants Ltd. and B.C. Research Council to characterize contaminants and product streams and to quantify worker exposure to selected potentially hazardous airborne contaminants in four Canadian coal liquefaction pilot plant facilities. In fiscal year 1983-84 this work was expanded to include the development of better analytical methods for exposure monitoring (because standard procedures for polycyclic aromatic hydrocarbons (PAH) analysis may underestimate exposure to the more volatile compounds from this class) and to determine the toxicity of contaminants to which workers may be exposed through skin contact. The results obtained to date indicate worker exposure to low levels of aromatic amines, PAH, benzene, toluene, xylene, hydrogen sulphide and mercaptans.

Concord Scientific Corporation has determined (for HWC) the methanol exposure of pump attendants and mechanics servicing vehicles fueled with gasoline/methanol blends. This study was conducted in Winnipeg, Manitoba.

The Wastewater Technology Centre in Burlington, Ontario, has conducted (for EC) a literature search on and gathered information about the four most economically viable coal liquefaction processes and waste treatment technologies. Only the H-Coal process was in operation in North America at a scale to produce sufficient quantities of wastewaters for water treatment experiments.

Wastewaters from coal liquefaction processes are known to contain a wide range of toxic and inhibitory compounds including ammonia, phenols, cyanides, thiocyanates, PAHs and HNCs. In order to address the removal of these pollutants, experimental work focussed on the biological fluidized bed treatment of the condensates with pretreatment either by solvent extraction or via high-rate anaerobic biotechnology. Solvent-stripped condensates have been

successfully nitrified and denitrified with concomitant removal of the above pollutants. Alternative pretreatment using novel anaerobic reactor systems has successfully treated a 40% concentration of raw condensate. The importance of this result lies in the fact that the bulk of phenolic compounds have been converted to a methane by-product which can be used to close the energy gap of the treatment scheme.

At EC, analytical methods were developed for upgrader wastes (e.g. sludges, residues). The implications of development of upgrading technologies were assessed. Gas plant wastes were characterized and treated. A joint Canadian Petroleum Association/Environmental Protection Service instruction manual was prepared for the oil and gas industries' use. The manual outlines a procedure for characterizing and determining the environmental significance of waste sludges generated by the LNG and LPG processing industry.

ANNEX A

LIST OF PUBLICATIONS, CONTRACTS AND REPORTS

GENERATED BY THE NEW LIQUID FUELS TASK

Techno - Economic Analyses

1. Optimized Linear Program Analysis of the Effect of Oxygenated Fuels on Canadian Oil Refineries, T.H. Wise and W.A. Grattendick, Hycarb Engineering Ltd., Calgary, March 1985.

2. The Possible Use of Methanol Blends for Canada's Road Vehicles, a Policy Oriented Analysis, Bureau of Management Consulting, Project No. 2-4532, September 1984.

3. Economic Assessment of Propane and Natural Gas as Transportation Fuels, N. Huckvale, Transportation Energy Division, EMR, February 1985.

4. Alternative Fuel Cost Study, R.F. Webb Corporation Ltd., Padgett Process Services Ltd. and W.G. Matthews Associates Ltd., prepared for MOSST, March 1984.

5.1 DIRECT LIQUEFACTION PROGRAM

Coal Co-processing Reports

1. The Co-Processing Behaviour of Cold Lake Vacuum Bottoms and an Alberta Subbituminous Coal, S.A. Fouda, J.F. Kelly and P.M. Rahimi, ERP/ERL 82-53(CF), EMR, 1982.

2. The Co-Processing of an Alberta Subbituminous Coal and Distillate Fraction of Cold Lake Heavy Oil, S.A. Fouda and J.F. Kelly, ERP/ERL 83-45(CF), EMR, 1983.

3. The Nature of Products from the Liquefaction of Subbituminous Coals in the Presence of Petroleum Related Residues, S. Ahmed, S.A. Fouda, P. Rahimi and H. Sawatzky, ERP/ELR 83-51(OP), EMR, 1983.

4. Compound Type Studies of Co-Processing Products of Cold Lake Vacuum Bottoms and an Alberta Subbituminous Coal, S. Ahmed, S.A. Fouda, P. Rahimi and H. Sawatzky, ERP/ERL 83-22(CF), EMR, 1983.

5. Analysis of Co-Processing Distillation Residues Boiling Above 524°C by Pyrolysis TLC and Solid State Carbon-13 NMR, M. Poirier, P. Rahimi, S.A. Fouda and S. Ahmed, ERP/ERL 83-03(CF), EMR, 1983.

6. Quantitative Analysis of Coal-Derived Liquids Residues by TLC with Flame Ionization Detection, M.A. Poirier, P. Rahimi, and S.M. Ahmed, ERP/ERL 83-13(OP,J), EMR, 1983.

7. The Nature of Products from the Liquefaction of Subbituminous Coals in the Presence of Petroleum Related Residues, S.M. Ahmed, S.A. Fouda, P.M. Rahimi and H. Sawatzky, ERP/ERL 83-65(TR), EMR, 1983.

8. The CANMET Co-Processing R&D Program - an Executive Summary, J.F. Kelly, ERP/ERL 83-86(CF), EMR, 1983.

9. A Briefing Report on Canadian Participation in the U.K. Point-of-Ayr Coal Liquefaction Pilot Plant Project, J.F. Kelly, ERP/ERL 83-23(CF), EMR, 1983.

10. The Co-Processing of an Alberta Subbituminous coal and Cold Lake Vacuum Bottoms using Synthesis Gas: I-Gross Performance, M. Itura, S.A. Fouda, and J.F. Kelly, ERP/ERL 84-26(CF), EMR.

11. The Co-Processing of an Alberta Subbituminous Coal and Cold Lake Vacuum Bottoms using Synthesis Gas: II-Characteristics of Distillates. M. Ikura, S.A. Fouda, and J.F. Kelly, ERP/ERL 84-29(CF), EMR.

12. The Co-Processing of an Alberta Subbituminous Coal and Cold Lake Vacuum Bottoms using Synthesis Gas: III-A Proposal on Two Stage Co-processing, M. Ikura, S.A. Fouda, and J.F. Kelly, ERP/ERL 84-47(CF), EMR.

13. Hydrocarbon-Type Analysis of Distillate Products Obtained under Co-processing Conditions using a Thin Layer Chromotography Analysis Technique, P.M. Rahimi, M. Ikura, S.A. Fouda, and J.F. Kelly, ERP/ERL 84-03 (CF), 1984.

14. Are Bitumens/Heavy Oils Hydrogen Donons - Quantitative Determination of Hydrogen Donor Abilities of Bitumens and Pitch Materials using 1, 1 - Binaphthyl and Anthracene, P.M. Rahimi, J.T. Price and J.F. Kelly, ERP/ERL 84-18(CF), 1984.

15. Co-processing Behaviour of Cold Lake Vacuum Bottoms and Forestburg Subbituminous Coal using H_2S as a Catalyst, P.M. Rahimi and J.F. Kelly, ERP/ERL, 84-21(CF), 1984.

16. The use of H_2S as a Promotor for the Water-Gas Shift Reaction under Co-processing Conditions, P.M. Rahimi and J.F. Kelly, ERP/ERL 84-34(CF), 1984.

17. Behaviour of Forestburg Subbituminous C Coal and Cold Lake Vacuum Bottoms during Co-processing with Syngas and H_2S, P.M. Rahimi and J.F. Kelly, ERP/ERL 84-35(F), 1984.

18. Cold Lake Heavy Oil Fractions as Co-processing Media, S.A. Fonda, and J.F. Kelly, ERP/ERL 84-25(CF), EMR, 1984.

19. Co-processing of Canadian Lignites and Bitumen, S.A. Fouda, M. Ikura, and J.F. Kelly, ERP/ERL 84-44(OP-J), EMR, 1984.

20. CANMET Co-Processing: A Status Report, J.F. Kelly, S.A. Fouda, P.M. Rahimi, and M. Ikura, ERP/ERL 84-52(OP-J), EMR, 1984.

21. Techno-Economic Evaluation of Synthetic Fuels from Coal-Heavy Oil Mixtures, Synthetic Fuels Associates (Palo Alto, Calif.), final letter report for EMR Canada, January 1983, CONFIDENTIAL.

Coal Co-Processing Contracts

1. Quantitative Analysis of Coal in the Presence of Coke using FTIR, Raylo Chemical Company, report to be prepared.

2. Demonstration and Testing of the Use of Hydrogen Sulfide as a Promoter in Coal Liquefaction, Sandwell Beak Research Group, three confidential reports have been prepared.

3. Characterization of Solid Residues from Coal Liquefaction Processes, University of Regina, Energy Research Unit, 1984.

4. Investigation to Determine the Feasibility of Using Bitumen as Solvent for Coal Liquefaction, final report by Sandwell Beak Research Group for EMR Canada, January 1980, CONFIDENTIAL.

5. Thermal Hydrogenation of Bitumen/Coal Slurries using Simulated Syngas, final report by Saskatchewan Power Corporation for EMR Canada, July 1981, CONFIDENTIAL.

6. Evaluation of the Sandwell CENTRAX Process for the Separation of Solids and Recovery of Liquid Products from Ten Different Samples of Slurry, Sandwell Beak Research Group, final report to be prepared.

Coal Liquefaction

1. Results of Liquefaction Tests on Coal Samples Offered by the Canadian Coal Liquefaction Coordinating Committee, Y. Ogisu, Y. Kuriki, Y. Otaka and S. Fujita, New Energy Development Organization (NEDO), Japan, presented at the Coal Liquefaction Contractors' Review Meeting, Ottawa, 1982.

2. Liquefaction of Nova Scotia Coals, J.J. Starzomski, D.M. Jay and J.K. LeDue, presented at the Coal Liquefaction Contractors' Review Meeting, Ottawa, 1982.

3. A Program of R&D on the Pyrolysis of Coal - The CANMET Flash Hydropyrolysis Program, N.E. Anderson and C.C. Chao, Ontario Research Foundation, presented at the Coal Liquefaction Contractors' Review Meeting, Ottawa, 1982.

4. Physical and Chemical Factors Affecting Supercritical Gas Extraction of Canadian Coals, J.F. Prescrott and P.B. Van Bostelen, Raylo Chemicals, presented at the Coal Liquefaction Contractors' Review Meeting, Ottawa, 1982.

5. Pyrolysis Screening Tests on Canadian Coals, D.S. Scott, J. Piskorz and S.A. Fouda, CANMET, presented at the Coal Liquefaction Contractors' Review Meeting, Ottawa, 1982.

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NOTE: Several of the EC projects have fostered publication of technical papers not listed here.

ANNEX B

CANMET'S COAL LIQUEFACTION

CONTRACTORS' FINAL REPORT LIST

February 1985

CONTRACTORS' FINAL REPORT LIST

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
Coal conversion in Alberta: Stage 1	Algas Resources Ltd.	18SQ.23440-6-9086-1	OSQ76-00158	M. Ternan	Sept. 1977	82-4611 82-4612	582
Coal liquefaction plant feasibility study	Algas Resources Ltd.	18SQ.23440-8-1925-4	OSQ79-00130	M. Ternan	March 1981		
Phase I - Executive summary						82-2973	17
Vol. I - Technical						82-2974	186
Vol. II - Cost estimate and economic evaluation						82-2975	167
Book I - Vol. III - Conceptual flowsheets and material balances						82-2976	130
Book II - Vol. III - Process specifications and equipment data sheets						82-2977	301
Petroleum coke - supply, demand, cost 1974-1990 and technical and economic appraisal of pure electrode coke by solvent refining of Canadian coals	Aluminum Company of Canada	18SQ.23440-6-9086-9	OSQ76-00156	D. Montgomery	April 1978	(Backfile)	67
Western Canada coal liquefaction study - prefeasibility study, Phase I	British Columbia Resources Corp.	23SQ.23440-1-9030	OSQ81-00057	D. Brown/ D. Faurschou	May 1982	83-3127	666
	Petro-Canada Exp. Inc. Westcoast Transmission Co. Ltd. British Columbia Coal Ltd. (Kilborn Eng.)						
Fluidized bed gasification of fine coal waste	B.C. Research	23440-7-9068	OSQ77-00269		June 1978	(Backfile)	113

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
Coal liquefaction by concurrent grinding and hydrogenation	B.C. Research	18SQ.23440-7-9073-viii	OSQ78-00010	K. Belinko	August 1979	82-0496	86
Continuous liquefaction of Hat Creek Coal	B.C. Research	15SQ.23440-3-9060	OSQ83-00060	S.A. Pouda		Available 1985	
Liquefaction of low rank coals - Phase I	Beak Consultants	18SQ.23440-7-9059	OSQ77-00131	J.F. Kelly	May 1978	(Backfile)	267
Liquefaction of low rank coals - Phase II	Sandwell Beak Research Group	18SQ.23440-8-9024	OSQ78-00090	J.F. Kelly	April 1980	81-0628	347
Investigation to determine the feasibility of using bitumen as solvent for coal liquefaction - Phase I, II	Sandwell Beak Research Group	19SQ.23440-8-9104-1 19SQ.23440-0-9047	OSQ79-00100 OSQ80-00067	J.F. Kelly	Jan. 1980	Confidential	
Study relating to the production of oil from low rank Canadian coals by continuous liquefaction - Phase I	Sandwell Beak Research Group	18SQ.23440-8-9125-2	OSQ79-00061	J.F. Kelly	Aug. 1982	(Backfile)	72
Study relating to the production of oil from low rank Canadian coals by continuous liquefaction - Phase II, III	Sandwell Beak Research Group	23SQ.23440-0-9170 23SQ.23440-1-9031	OSQ81-00022 OSQ81-00024	J.F. Kelly	Oct. 1983	84-1175	103
Study relating to the production of oil from low rank Canadian coals by continuous liquefaction - Phase IV	Sandwell Beak Research Group	23SQ.23440-2-9199	OSQ82-00277	J.F. Kelly	July 1983	Available after July 1985	75
Demonstration and testing of the use of H_2S as a promotor on coal liquefaction	Sandwell Beak Research Group	23SQ.23440-3-9198	OSQ83-00185	P.M. Rahimi		Confidential	
A study to evaluate and compare the production costs of liquid fuels from coal and from oil sands in Alberta	Dynawest Projects Ltd.	23SQ-23440-1-9059	OSQ81-00113	H. Sawatzky	Feb. 1983	Available Jan. 1985	125
Production of liquid fuel from coal progress report No. 1	Inco Metals Co.	01SU.23440-7-9123	OSQ77-00184	J.F. Kelly	March 1978	(Backfile)	42

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
Development of equipment and process information related to the flash hydro-pyrolysis of coal	Kilborn Limited	18SQ.23440-9-9151	OSQ80-00019	P. Sears	Jan. 1984	Available Dec. 1984	102
Investigation of coal liquefaction processes	McGill University	07SU.23440-8-9105/2	OSU79-00193	A. Slazdow	April 1980	82-0478	42
Extractive coking liquefaction process	Nova Scotia Research Foundation Corp.	18SQ.23440-6-9086	OSQ76-00154	J.P. Kelly	June 1977	(Backfile)	54
Low severity coal liquefaction process	Nova Scotia Research Foundation Corp.	23SQ.23440-1-9059	OSQ81-00113	H. Sawatzky	Feb. 1983	Available Jan. 1985	125
Liquefaction of Nova Scotia Coals, Phase IV	Nova Scotia Research Foundation Corp.	23SQ.23440-0-9172	OSQ81-00039	D. Paurschou	Aug. 1983	84-1176	156
Liquefaction studies of Nova Scotial coals, Phase V	Nova Scotia Research Foundation Corp.	28SQ.23440-3-9073	OSQ83-00079	D. Paurschou		Available 1985	
Supercritical gas extraction of Canadian coals	Raylo Chemicals	23SQ.23440-8-9091	OSQ79-00114	A. George	Feb. 1982	80-4659	30
Supercritical gas extraction of coal: investigation of the chemical and physical factors	Raylo Chemicals	23SQ.23440-0-9111	OSQ80-00186	P. Sears	April 1982	(Backfile)	81
Optimization, chemistry and product analysis of supercritical gas extraction techniques for the liquefaction of Canadian coals	Raylo Chemicals	23SQ.23440-9-9169	OSQ80-00011	A. George	March 1981	82-1540	80
Quantitative analysis of coal in the presence of coke using Fourier transform infrared spectroscopy	Raylo Chemicals	26SQ.23440-2-9096	OSQ82-00109	P. Rahimi	April 1983	Confidential	
Supercritical gas extraction of Nova Scotia coal	Raylo Chemicals	26SQ.23440-2-9098	OSQ82-00108	P. Sears	April 1983	Available 1985	50
The characterization of coal derived liquids	Raylo Chemicals	18SQ.23440-9-9157	OSQ79-00195	M. Poirier	May 1982	83-4005	59

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
Petrographic analyses of coal conversion feedstocks and residues - Phase I	University of Regina	19ST.23440-8-9113	OST79-00030	K. Belinko	March 1980		265
Characterization of solid residues from coal liquefaction processes	University of Regina	14SU-23440-9-9177	OSU80-00088	J.T. Price	March 1981	82-4620	292
Characterization of solid residues from coal liquefaction processes	University of Regina	OIST-24440-2-9102	OST82-00067	J. Price	June 1983	84-0756	144
Characterization of solid residues from coal liquefaction processes	University of Regina	24SU-23440-3-9113	OSU83-00127	W.D. Dawson	May 1984	Confidential	
Study relating to the technical and economic feasibility of lignite liquefaction in Saskatchewan	Saskatchewan Oil & Gas Corp.	23SQ.23440-2-9203	OSQ82-00269	L. Mysak	Oct. 1982	84-3984	1251
Determination of rheological properties of coal-oil slurries	Saskatchewan Research Council	18SQ.23440-7-9073-VII	OSQ77-00263	G.N. Banks	Feb. 1981	82-1535/2	102
Technical assessment of coal liquefaction processes for Canada	SNC	18SQ.23440-9-9036	OSQ79-00090	M. Ternan	Sept. 1981	82-3658 82-3666	1387
Beneficiation of coal by oxygen removal	SNC	18SQ.23440-8-9090	OSQ82-00110	E. Purimsky	March 1983	Available Dec. 1984	43
Investigation to develop innovative methods for the removal of oxygen from coals	SNC	23SQ.23440-1-9034	OSQ81-00053	E. Purimsky		Available Dec. 1984	42
Determination of the feasibility of designing process development unit for the commercialization of a spouted bed gasifier	SNC	23SQ.23440-1-9063	OSQ81-00193	G. Sirianni/ M. Skubnik	July 1982	83-2873	174
Development design and construction of a computer design model program of Venturi gas scrubbers employing molten salt	SNC	03SQ.23440-1-9099	OSQ82-00045	V.R. Marwaha	Aug. 1983	Available Dec. 1984	287

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
Application of fluid bed gasification technology and absorbents (dolomite, limestone, oil shale) for utilization of high sulphur New Brunswick coal	SNC	23SQ.23440-2-9104	OSQ82-00158	D. Fung	Jan. 1983	Available Dec. 1984	113
Technoeconmic evaluation of synthetic fuels from coal-heavy oil mixtures	Synthetic Fuels Associates	03SQ.23440-2-1940	OSQ82-00133	J.P. Kelly/ M. Ikura	Jan. 1983	Confidential	
Short residence time pyrolysis of coal	University of Waterloo	20SU.23440-1-9032	OSU81-00087	J.P. Kelly/ S. Fouda	June 1982	83-0025	72
Screening program on short residence time pyrolysis of coal	University of Waterloo	14SU.23440-2-9101	OSU82-00255	S.A. Fouda		Available 1985	
Direct coal liquefaction under ambient conditions	University of Victoria	12ST.23440-4-9029	OST84-00012	P.M. Rahimi		Confidential	
Characterizaton of liquid fuels from spouted bed pyrolysis of Canadian Coals	University of British Columbia	20SU.23440-2-9093	1SU82-00245	M. Skubnik	July 1984	Available Dec. 1984	157
Spouted bed gasification of Western Canadian coals - Final report 1979/80	University of British Columbia	18SQ-23440-8-9111	OSU79-00065	G.V. Sirianni	April 1980	80-4670	40
Spouted bed gasification of Western Canadian coals - Final report 1980/81	University of British Columbia	20SU.23440-0-9152	OSU80-00068	G.V. Sirianni	May 1982	83-2866	39
Spouted bed gasification of Western Canadian coals	University of British Columbia	20SU.23440-0-9143	OSU81-00074	G.V. Sirianni	May 1982	83-2866	39
Continued study of spouted bed gasification of Western Canadian coal	University of British Columbia	OSU.23440-2-9000	OSU82-00138	K. Thambimuthu/ G. Sirianni	May 1983		44
A review and assessment of processes for indirect liquefaction of Ontario lignite into methanol and other liquid fuels - A 50/50 shared-cost contract	Ontario Energy Corp.	17SQ.23440-2-9092	OSQ82-00201	D. Fung	June 1984	Confidential	82+ App.

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
A study of the suitability of British Columbia and Nova Scotia coal resources for underground gasification:	B.H. Levelton & Associates						
Phase 1 - Underground coal gasification technology and site selection criteria		23SQ.23440-9-9175	1SQ80-00057	R. Sage	Jan. 1981	82-1531	143
Phase 2 - Evaluation of the suitability of British Columbia and Nova Scotia resources		23SQ.23440-9-9175	1SQ80-00057	R. Sage	March 1981	82-1533	233
Appendix A-1 - Coal resources of British Columbia		23SQ,23440-9-9175	1SQ80-00057	R. Sage	March 1981	82-1532	157
Appendix B - Coal resources of Nova Scotia		23SQ.23440-9-9175	1SQ80-00057	R. Sage	March 1981	82-1534	139
Geological characteristics of the Bowron and Tulameen coalfields of British Columbia		23SQ.23440-9-9175	0SQ80-00057	R. Sage	June 1982	84-0043	21
A study of the feasibility of underground coal gasification in the Bowron and Tulameen coalfields of British Columbia	B.H. Levelton & Associates	23SQ.23440-2-9018	0SQ80-000217	D. Fung	Feb. 1983	84-0043	127
Development of bench scale fluid bed gasifier and gas burner system	Carleton University		0SU77-00413	L. Mysak	Aug. 1979	80-0494	79
Product control in fluid-bed gasification and low BTU gas burner	Carleton University	8-9112	0SU78-00368		May 1980	81-1174	33
Shaunavon coal utilization study:	Saskatchewan Power Corp.						
Phase I - 300 MWe AFBC fired power generation plant		18SQ.23440-8-9059	0SQ78-00110	G. Sirianni	April 1979	Available Dec. 1984	79

REPORT TITLE	CONTRACTOR	DSS FILE NUMBER	DSS CONTRACT SERIAL NUMBER	CANMET SCIENTIFIC AUTHORITY	DATE COMPLETED	MICROMEDIA ORDER NUMBER	PAGES
Phase II - Comparision of schemes		18SQ.23440-8-9059	OSQ78-00110	G. Sirianni	July 1980	82-0468	271
Phase III - Water and environment		18SQ.23440-8-9059-2	OSQ78-00110	G. Sirianni	March 1978	Available Dec. 1984	244
Small gasifier applications	Saskatchewan Power Corp.	18SQ.23440-7-9055-2	OSQ78-00019	G. Sirianni	Feb. 1979	81-1909	172
Gasification and petrographic studies of Saskatchewan lignites	Saskatchewan Power Corp.	18SQ.23440-7-9073	OSQ78-00023	G. Sirianni	April 1979	79-5516	216
A technical and economic assessment of the reactivity of Saskatchewan lignite coals as they relate to gasification processes:	Saskatchewan Power Corp.						
Lignite reactivity - II		18SQ.23440-8-9125-1	OSQ79-00053	L.P. Mysak	May 1980	80-4665	116
Phase III		18SQ.23440-9-9153	OSQ80-00032	L.P. Mysak	April 1982	83-2942	125
Phase IV - Final report		23SQ.23440-0-9139	OSQ81-00093	L.P. Mysak	April 1983	84-1278	70
Final report		23SQ.23440-2-9014	OSQ77-00269		June 1978	(Backfile)	113
Thermal hydrogenation of bitumen/coal slurries using simulated syngas	Saskatchewan Power Corp.	19SQ.23440-8-9104-2	OSQ79-00086	C. Khulbe	July 1981	Confidential	
Study of high temperature gas clean-up	Ebastec Lavalin	03SQ.23440-2-9021	OSQ83-00127		May 1983	84-1182	275
Development of fluid bed gasification control parameters for a range of Canadian coals:	Asecor Ltd.						
Phase III - Final report		13ST.23440-9-9149	OST80-00006	L. Mysak	Nov. 1981	83-0054	93
Phase IV - Final report		23SQ.23440-9-9140	OSQ81-00036	L. Mysak	July 1982	83-2111	56